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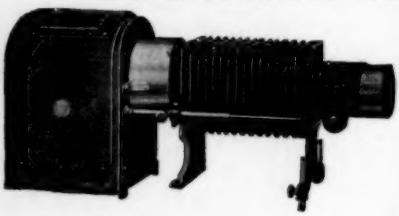

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SCHOOL SCIENCE AND MATHEMATICS

VOL. XVIII, NO. 1 JANUARY, 1918 WHOLE NO. 147

CONCERNING EXPERIMENTS TO TEST THE TRANSFER OF TRAINING.

BY J. W. A. YOUNG,

The University of Chicago.

What follows is written from the point of view of a worker in mathematics who usually turns to that subject for his concrete illustrations; but the discussion is not, in the main, more relevant to the subject of mathematics than to other subjects.

For many centuries, mathematics has been taught in the belief not only that much of its content is of great practical usefulness, but also that a suitable study of the subject affords valuable mental training. So widespread has been this belief, and so satisfactory the outcome of the myriad annual repetitions of the test in the laboratory of experience, that up to this day mathematics is taught as a subject required of all in the elementary and secondary schools of practically the whole civilized world.[1] The belief was based at each period on general educational theory current at that time, supported by the outcome in practice. It was by no means *proved* to be correct in the sense in which proof is understood in mathematics.

Within the last decade or two, however, a more or less definite impression has gained currency to the general effect that psychologists have been making laboratory investigations of the processes of mental training whose results have *proved* that mental power gained in the study of some one subject cannot be applied in another; that old "doctrines" have been "exploded"; that the day of educational theorizing is past; that henceforth educational problems will be taken into the psychological laboratory and *solved;* that a formula for dealing

[1]Moreover, there is a remarkable similarity in the scope and even in the details of the ground covered, as well as in the character and the methods of instruction. It is the judgment of all civilization that a certain minimum of mathematics, which is about the same the world over, should be obligatory for all pupils. (See the reports presented to the International Congress of Mathematicians at Cambridge, England, in 1912. With respect to curricula, these reports have been summarized by J. C. Brown, in Bulletin No. 619, 1914, of the U. S. Bureau of Education, Washington, D. C. As long as the supply lasts, the Bulletin may be obtained free on application to the Bureau).

with each particular problem will be discovered and *proved*, just as in mathematics. Naturally, all this must be very pleasing to those working in the field of mathematics—the science of actual proofs. One imbued with the mathematical ideal will always prefer to base his actions on facts, on known truths, rather than on theorizings and suppositions. But, of course, he will wish to get his facts at first hand, or as nearly so as possible. In the particular matter in question, he would certainly wish to learn from the psychologists themselves what they have proved, and not at second, third, or *n*th hand

With this attitude of mind, I began a goodly number of years ago to try to ascertain from psychologists in person and in their own first-hand publications, just what they have actually accomplished; what are the known *facts* concerning transfer of training.

And on entering the field of first-hand psychological literature itself, I found, just as I expected to find, the calm and serene atmosphere of science. I found careful statement of particular experiments and not sweeping generalizations on the basis of meager data; I found that psychologists of the first rank were quietly doing their work and presenting the results for what they might be worth; and that the explosions which were to overturn the entire educational edifice were taking place chiefly in the regions of rumor and misconception.

So far as I myself was concerned, I found nothing that was not consonant with the views that I had held as to the purpose and value of the study and teaching of mathematics in elementary and secondary schools. In fact, I found myself confirmed and supported in those views. But I had no means of knowing that I had found all the relevant literature, and I hesitated at offering to a wider public a summary of the facts as I had found them, lest it should turn out that I had not found and considered results of dominating import.

But, fortunately, a recent publication enables me to present such a summary with a certificate of completeness from a prominent psychologist who is an authority in this particular field. Namely, in *Monograph No. 16* of the *Educational Psychology Monographs*, the editor, Professor Guy Montrose Whipple, of the University of Illinois, states that this "monograph presents in a compact, semitabular form, a valuable and comprehensive

summary of all the experimental work that has been done upon formal discipline to date."[2]

With the boundary of completeness thus authoritatively fixed, I present in the sequel a brief sketch of the experiments listed by Rugg. The presentation is based in part on the original memoirs, in part on Rugg's monograph, whose order I follow. It is obvious that any description in a few words of a voluminous memoir must be indequate. The most that can be hoped is that these few words may give the reader a general idea of the character of the psychological investigations in question and of their results.

The theorizing, I leave to the reader. This bird's-eye view puts him into the position to do the following:

(1) To examine the literature in detail, by following up the references given.

(2) To decide for himself, what modifications, if any, the results of these experiments require him to make in the views he has hitherto held as to the purpose and value of the teaching of his subject.

(3) To pass intelligent judgment upon claims that may be made at second, third, or *n*th hand to the effect that psychologists have "proved" this or "exploded" that.

Detailed references to the original publications concerning each experiment are given in a table at the end of the paper. In addition, mention should be made of:

Thorndike, E. L., *Educational Psychology*, 3 vols. 2d ed., New York, 1913-14.

Heck, W. H., *Mental Discipline and Educational Values*. London and New York, 1912.

But one reading in this field for the first time should by all means begin with Rugg's monograph.

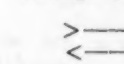
[2] The monograph in question is entitled, *The Experimental Determination of Mental Discipline in School Studies*, by Harold Ordway Rugg. Published by Warwick & York, Baltimore, Md., 1916.

Professor Whipple was formerly connected with Cornell University; he is one of the Editors of the *Journal of Applied Psychology* and also one of the editors of the *Journal for Educational Psychology*, the chief single organ in the United States of the type of work here under consideration. He is the author of a *Manual of Mental and Physical Tests* (second edition, revised and enlarged, 2 vols., together 717 pp., large 8vo., 1914-15), which impresses me as a thorough and scholarly work, full, clear, and easily readable. In the *Psychological Bulletin*, March, 1917, p. 105, it is stated that this manual "serves as the standard reference book to which one who is to make tests naturally turns to consult before determining upon his method and to get a starting point for a study of the literature."

Accordingly, Professor Whipple speaks with the authority of a specialist of high standing in this very field when he tells us that Rugg's monograph covers "all the work done upon formal discipline to date."

Of course, I take this statement in a figurative rather than in a strictly literal sense. It is difficult to guarantee literal completeness. I know of researches (some of them indeed listed in Whipple's bibliographies, and doubtless he and Dr. Rugg know of still others), for whose inclusion a more or less strong claim might be made. But their inclusion would not alter the total picture. I accept Whipple's guarantee to the effect that we have in the researches listed a picture that is essentially complete and that we can from it ascertain the actual upshot of the experimental work to date. If anyone should wish to question this, it would not be sufficient to claim that certain other investigations should have been included; this would be a mere quibble unless accompanied by proof that their inclusion would have altered the outcome materially.

Power Trained, Studied, or Tested.	Remarks; Results.
I. James, 1890. Memorizing verse.	Practice in memorizing verse by other writers caused little or no improvement in memorizing verse by a given writer. The conditions of the experiment are not exactly stated.
II. Peterson, 1912. James' experiment repeated.	Considerable improvement followed training. But several of the untrained control group showed as much gain.
III. Ebert and Meumann, 1904. Memorizing series of numbers, nonsense syllables, letters, unrelated words, stanzas of poetry, paragraphs of prose.	The training and test series were of the same general character. On the whole, marked improvement in ability to memorize them was found after training.
IV. Dearborn, 1909. Repeated Ebert and Meumann's test series to find what improvement is obtained from practice incident to the tests.	Found large improvement of this character.
V. Dearborn, 1910. Memorizing English, French, German, Norse verse, etc.	Six subjects were trained on French or German vocabularies, six on various kinds of verse. Almost all showed improvement in the test material, though not so much as in the training material. Thus, a subject who was trained on French vocabulary and showed fifty-seven per cent gain therein, showed twenty-five per cent gain in (untrained) memorizing of French verse. One trained on Horace's Odes with a gain of seventy-three per cent, showed a gain of but seventeen per cent in (untrained) memorizing of Norse poems. A gain of sixty-eight per cent in memorizing "Paradise Lost" was followed by no gain in (untrained) memorizing of chemical formulas.
VI. Winch, 1908. Memorizing passages from book on history for ten minutes with reproduction at once.	Group A was trained for two weeks in memorizing poetry. Group B worked sums while Group A practiced memorizing. Otherwise the work of the two groups was exactly the same. Group B showed marked improvement in the test memorizing. Group A showed slightly more. The experiment was repeated with different groups with the same results.

VII. Fracker, 1908.	
Memory for:	
Poetry.	Practice was given on memorizing the order of four tones.
Order of four shades of gray.	The practiced group (eight individuals) made a greater percentage of improvement in each type of memory tested than did the untrained group (four individuals).
Order of nine tones.	
Order of nine shades of gray.	
Order of four tones.	The greatest difference of improvement was found in the case of four grays, the next in the case of four tones, and the least in the memory for the extent of arm movement.
Order of nine geometric figures.	
Order of nine numbers.	
Extent of arm movement.	
VIII. Winch, 1910.	
Memory for substance of passages read.	Rote memory gained by practice; substance memory showed some improvement.
IX. Sleight, 1911.	
Ability to memorize spatial relations, dates, nonsense syllables, poetry, prose, etc.	Groups of girls and women were trained in various types of memorizing. The untrained control groups showed practically as much gain as the trained groups. Over one hundred persons altogether.
X. Thorndike, 1901.	
Estimating areas of rectangles.	Training on rectangles of a certain shape produced improvement for rectangles of the same area but different shape, though the degree of improvement was not so great as in the training set.
Estimating weights.	Analogous results.
Perceiving words containing two given letters.	Training in perceiving words containing *e* and *a* gave improvement in perceiving words containing other combinations, as *i* and *l*, *s* and *p*, *c* and *a*, *e* and *r*, and in perceiving A's and misspelled words, but the improvement was not so great as for the combination used in training.
Perceiving a given part of speech.	Training in verbs produced a slight reduction for other parts of speech accompanied by an *increase* of over one hundred per cent in omissions.
XI. Judd, 1902.	
Strength of the illusion:	Two subjects (trained observers) were given practice on hundreds of such figures. The illusion gradually disappeared. There was transfer of skill gained by practice, in spite of varying conditions.
	
XII. Coover and Angell (F), 1907.	
Discrimination of shades of gray.	Four individuals were given practice in discriminating intensity of sound. All the individuals but one showed improvement in discriminating shades of gray. No untrained comparison group is mentioned.

XIII. Bennett, 1907. Discrimination between: Shades of red. Shades of yellow and green. Shades of black and orange.	Sixteen children, aged about eleven, were trained in discriminating between shades of blue. There was marked improvement in discriminating between the other shades. No untrained comparison group is mentioned.
XIV. Scholkow and Judd, 1908. Holding pencil in direction indicated by lines.	Practice with one line, affected success with all other lines.
XV. Kline, 1909. (1) Cancelling parts of speech. (2) Substituting digits for other symbols, and vice versa.	Subjects were trained in crossing off *e*'s and *t*'s; also in substituting digits for letters. In the final tests, they showed: In (1), only a slight gain. In (2), much less improvement in the test series than in the training series; in a few cases, there was actual retrogression on the test series.
XVI. Wallin, 1910. Control of reversions in reversible perspective outlines (such as pyramids, etc.).	Training of one eye caused gain in the unpracticed eye.
XVII. Whipple, 1910. Influence of training on quickness of visual perception.	Nine subjects were trained by objects exposed for a short time; e. g., cards with five to seven printed letters, were exposed 8/100 sec.; stanza of poetry exposed three seconds. The effect of training was little or nothing.
XVIII. Foster, 1911. Somewhat analogous to the work of Whipple.	Three adults were trained and showed only slight improvement.
XIX. Dallenbach, 1914. Analogous to the work of Whipple.	Twenty-nine school children were trained, and there was a control group of fifteen untrained children. The effect of training persisted fifty weeks and spread to other functions.
XX. Gilbert and Fracker, 1897. Reaction to stimuli: sounds, electric shocks, certain blows, sight of blue surfaces.	Three subjects were trained in reaction to sounds. If no discrimination is involved, the gain for other untrained stimuli is almost equal to that for those used in training. If the test required discrimination and choice but the training did not, there was no reduction after training. But practice in discrimination of sounds reduced the time of discrimination for other forms of stimuli.
XXI. Jastrow, 1896. Magicians Hermann and Kellar tested as to	Ability resulting from one very "specialized form of training may

	sensibility, quickness, estimates of distances, etc., in comparison with groups of college students.	be only slightly influential upon other forms of capacity."
XXII.	Bair, 1902. (1) Tapping letters on six labeled keys of typewriter. (2) Repeating alphabet forward, backward; also each way with letter *n* named between each letter.	The subjects were four college students. All showed decided effects of practice.
XXIII.	Leuba and Hyde, 1905. Reading German script; writing translations of it into English and vice versa.	Forty-two college students were trained in writing or reading German script. There was a large percentage of gain; as much as 230 per cent.
XXIV.	Ruger, 1910. Solution of mechanical puzzles.	There was evidence of some transfer.
XXV.	Bagley and Squire, 1905. Neatness.	For a period of three weeks, the teachers insisted on neatness in all work in arithmetic. There was an average gain of 4.1 per cent in neatness in arithmetic, but a *loss* of 2.1 per cent in language, and 2.3 per cent in spelling.
XXVI.	Ruediger, 1908. Neatness.	Thirty-nine children in seventh grade were divided into three groups. In each group, emphasis was put on neatness in *one subject* only, for a period of eight weeks. The percentage of gain in neatness was small but nearly as large in the subjects where no emphasis was laid on neatness as in those where it was emphasized.
XXVII.	Bennett, 1907. 1. Perception of pitch. 2. Perception of letters at different distances. 3. Reaction time. 4. Rate of marking A's. 5. Auditory memory of figures. 6. Logical memory of simple passages. 7. Quickness in naming colors.	College students were tested in the freshman year and again in the senior year. About five-eighths of the tests showed gains; the remainder showed no change or slower deterioration.
XXVIII.	Briggs, 1913. Influence of three months' training in formal grammar on such abilities as: To see likenesses and differences.	In instances there was evidence of some transfer. In the majority of cases there was no such evidence. W. C. Bagley points out various inadequacies in the conduct and

	To judge a definition. To make a rule. To select pertinent facts and use them properly.	the report of the experiment (*Jour. Educ. Psychol.*, September, 1914).
XXIX.	Wallin, 1911. Effect of drill in spelling.	All that is obtained from drill is increased facility to master new forms. Spelling drill does not "produce a universal, generalized spelling proficiency which will spread to *all* words whether these have been studied or not."
XXX.	Rugg, 1915. Effect of a semester's training in descriptive geometry on mental manipulation of spatial elements that are: (a) of nongeometric character; (b) quasi-geometric; (c) strictly geometric.	Four hundred and thirteen engineering freshmen studying descriptive geometry were compared with eighty-seven students of the College of Engineering and of Education not taking descriptive geometry. The study of descriptive geometry operated so as to increase substantially abilities in all lines mentioned.

The number of subjects that participate in an experiment is of considerable significance. If it is large, individual variations in conditions that affect the outcome may be regarded as more nearly averaged than when it is small. On account of the difference between adult and child psychology, results obtained by adults and children under the same conditions might well be quite different. In judging the import of the results of an experiment, it is of consequence to know whether or not there was formed for comparison a group of subjects who were not trained but who took the initial and final tests. In some cases, the number of subjects is mentioned in the summary above. The following table (based on Rugg, p. 11), gives the numbers for all the experiments. When various numbers participated in different parts of the experiment, the largest number is given. The subjects were adults, except when "ch" follows the number.

Experiment	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
Trained Group	5	2	6	?	12	27 ch.	8	23 ch.	18+84ch.	6
Untrained Group	0	7	0	?	0	27 ch.	4	23 ch.	?	0

Experiment	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.	XX.
Trained Group	2	4	16	3+1 Gp.Ch	9	2	6	3	29 ch.	3
Untrained Group	0	2	0	1 GroupCh.	9	0	0	0	15 ch.	0

Exp'm't	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVII.	XXVIII.	XXIX.	XXX.
Tr'n'd Grp.	2	4	26	27	1 Gp.Ch	39 ch.	145	130 ch.	1022 ch.	413
Untd. Grp.	1 Group	0	0	0	1 Gp.Ch	?	0	61 ch.	0	87

We have now before us a compact summary of "all the experimental work on formal discipline that has been done to date" (date of copyright, 1916). To determine what effect the results of this work should have upon educational views is an individual matter. The effect obviously depends upon what views the individual has held previously. Each individual must theorize for himself. If he considers the different mental powers to be "like different tanks or reservoirs with many pipes emptying into them and many draining out of them," and if he holds that "no matter through what pipe water gets into the tank it can go out by any other pipe and continue almost unchanged through the entire process,[3] he will find little support in the results of the above experiments. But who has ever held these views?

The reader who is disposed to do so may weigh the experiments by comparing the outcome that actually occurred with what his common sense would lead him to expect. If he finds, as I imagine he usually will, that the actual outcome agrees substantially with his common sense expectation, he will be encouraged to trust his common sense more than ever before, and will find in these experiments new support for the educational views which his common sense and experience had led him to hold.

As to bearing on transfer, Rugg classifies the experiments as follows:

(1)	Showing no transfer (including one doubtful)	5
(2)	Slight gain indicates some transfer	17
(3)	Clear evidence of considerable transfer	10
(4)	Experimenter claims large amount of transfer (unsupported by evidence)	3
		35

Five experiments were entered twice; two under (1) and (2), and three under (2) and (3). This accounts for the discrepancy between the thirty-five entries and thirty experiments.

Taken as a whole, the body of experiments tests discreet special abilities selected here and there from a very wide field and leaves many questions practically untouched, including the important one of training in reasoning. Almost none of the experiments have been repeated even a second time; the results are far from being scientifically established by numerous repetitions with concordant outcomes. What outcome there is gives distinct support to the belief that the results of training

[3] Heck, p. 160.

can be transferred, and that educational work has disciplinary as well as content value.

I add no further discussion for the present. In a subsequent paper, I shall give some of my own comments.

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THE FUNDAMENTAL RELATION OF BOTANY TO SCIENTIFIC AGRICULTURE.

By H. D. Waggoner,
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There is, at present, a strong sentiment coming from many quarters, against the old type of botany that has been, and is still, taught in many schools. The purely scientific study of plant life has lost ground, while the practical phases, which may be included, in a general way, under elementary agriculture, have gained rapidly. In these times of change in educational thought, there is great danger of going to extremes and thereby throwing aside much that is valuable. Consequently, a consideration of the fundamental relations of the scientific study of the plant to agricultural practices is in place.

The green plant occupies an entirely unique position in the world about us. It stands, as it were, between the organic and inorganic; between man's needs and the simple chemical compounds of the soil and air; between the sum and the energy requirements of virtually all living things. It is the green plant that is instrumental in bringing together the carbon dioxide of the air and the water of the soil, thereby producing the substance out of which the food supply of all higher forms of life, as well as that of the vast majority of the lower forms, is produced. The welfare of all living things is bound up with the welfare of the plant.

The green plant is the central figure of agriculture. The grain farmer, the stockman, the fruit grower, the gardener, all must sooner or later give it their most careful thought. The agronomist studies the chemistry of the soil; he adds limestone here and phosphate there; he investigates the effects of deep and shallow cultivation; he determines the crop rotation to be used; he studies the bacterial content of the soil and the effect of these organisms upon the availability of the mineral nutrients. All these investigations have a single aim—a better understanding of the conditions most favorable for plant life. The great central problem of present-day agriculture is concerned with the life of the plant and the necessary conditions for its optimum development and productivity.

If this is a true statement of the fundamental problem of agriculture, and I do not believe it can be questioned, if the plant stands at the focus of agricultural thought, and if the scientific investigations pertaining to the soil have as their final aim the improvement of the conditions for plant develop-

ment, then it follows that a clear and concise understanding of the fundamental structures and processes of the plant should be an essential part of any general course, worthy to be called scientific agriculture. The plant is a living thing and truly wonderful in its organization. It reacts to stimuli with precision. It ceases to develop when conditions are unfavorable for the carrying on of its life processes. It dies when subjected to influences to which the animal organism is immune. Identical causes will produce identical results here, as in the physical world. Law rules in the plant kingdom just as it rules elsewhere. Consequently, agricultural methods and practices must conform to the demands of the plant. If the plant fails to develop and to produce as it should, the manner and conditions of cultivation are at fault. Scientific agriculture must find the remedy. The knowledge of the structures and life processes of the plant itself is the only true, scientific guide to this end. It is true that valuable discoveries have been made by haphazard use of the "trial and error" method, without any knowledge of the organisms concerned, but this surely cannot be considered the true scientific procedure. True advance follows the investigation of the cause of a phenomenon. The time is not far distant when it will be generally recognized that it is just as important, from the standpoint of scientific advancement, for the agricultural student to understand the fundamental physiology of the plant, as it is for the medical student to understand the physiology of the human body. Surely, the proper kind of botany is essential in the study of scientific agriculture.

The kind of botany that will meet the needs of agriculture is a question of prime importance. The stand against botany as it has been, and still is, taught in many places, is, in my opinion, well taken. The botanists themselves are largely responsible for the condition. In this day when science is being applied so largely to the practices of everyday life, the demand has gradually arisen for the type of botany that will throw light upon the practical things in the home, on the farm, and in the community, concerning which there is a widespread and permanent interest. Instead of meeting this need, the botanist has been handing out a sort of boiled-down college botany suitable only for the specialist in biology—work that is of scientific interest, to be sure, but work that is of a type that scarcely touches the life of the average boy or girl, who, at most, can devote but a few months to this subject. This sort of botany

can have but a remote relation to agriculture. The botany that agriculture needs is, first of all, a scientific and thorough study of the fundamental structures and processes of plant life. The work must not be superficial. The few words devoted to the fundamental structures and processes of plants, as given in some very highly recommended agricultural texts, can never form a real basis upon which to build. In the second place, the material for study should be selected, as far as possible, from the important agricultural plants. The science of alfalfa and the corn plant is surely just as good as the science of the orchid and the marine alga. And, lastly, the fundamental and practical principles developed in these studies should be applied, where possible, directly to the agricultural practices without delay.

A course, such as this, is of great value, not only from the scientific but also from the applied standpoint. The principle developed in the study of the plant possesses a new meaning and an intensified interest when it is applied to the practical things of life. The scientific facts and principles underlying pollination, fertilization, and asexual reproduction, become subjects of supreme interest when they are connected up with things of practical life such as the selection of seed corn in the field, the breeding of animals and plants, and the preservation and multiplication of new varieties in horticulture. Where is the boy or girl who will be listless and inattentive as this tremendously important subject matter is carried over to explain the phenomena of everyday life! On the other hand, a boy who has a clear conception of the principle involved in an agricultural practice, becomes far more independent and intelligent in the application of this principle to the problems of the farm life. Surely it is hardly reasonable to expect a person to apply knowledge, intelligently, which he does not possess. It is true that a carefully worded direction may be followed, and good results obtained, so long as the conditions involved in the process remain unchanged, as is seen in the bread-making of our mothers, and in the legume crops of our fathers. But when the original set of conditions ceases to exist, and complications arise, then the knowledge of the principle involved becomes a necessity, if the person is to succeed in his undertaking. Doubtless the boy who is familiar with the life relations of the oat smut is more reliable when it comes to applying the formaldehyde treatment than he who blindly attempts to follow a set of directions.

There are difficulties to be encountered in the closely correlated courses of botany and agriculture that I am advocating. Too frequently the botany work is done by a teacher who knows almost nothing about the agricultural practices and has no conception of the problems the agriculturist must meet. With a teacher of this type, in a school where agriculture is an important line of work, I believe it is scarcely possible to have botany work that means much to those taking elementary agriculture. The teacher who does not have some definite knowledge of the practices and problems of the farm has little to guide him in his selection of suitable materials with which to develop principles that throw light upon the agricultural practices. Too frequently, also, the teachers of elementary agriculture, and sometimes those teaching advanced courses, have little conception of the important structures and fundamental processes of plant life. Under these conditions, the elementary agriculture is likely to degenerate into a superficial treatment of the subject that has no claim to be called scientific. An understanding of the principles involved, so far as it is possible to understand them, is a prime essential in a truly adequate course in scientific agriculture.

A man far advanced in his chosen line stood before his botany class composed largely of agricultural students, and virtually said to them by his manner and by his entire lack of knowledge concerning the common practices of agriculture, "I cannot help you in the application of these botanical principles, for I know nothing about agriculture, and, moreover, I care little about the subject. I am a botanist." Not far away another teacher, just ready to take the master's degree in agriculture, stood before his class in elementary agriculture and said in substance to his students, "You will recall that the *entire* root system of a plant is *completely* covered with root hairs, and that it is through these structures that the soil water enters the plant, after which it passes upward through the *cambium* layer." A splendid exhibition of profound ignorance of simple botanical facts! This actually took place, and, what is more, there is evidence that this sort of thing, in one form or another, is occurring all too frequently in our schools today. Such conditions should be unheard of where agriculture is taught, but this will come to pass only when teachers of botany and agriculture prepare themselves more broadly for their respective lines of work.

Closely correlated courses in the important phases of biology under consideration are scarcely possible, in my opinion, so long as the teacher of agriculture deals exclusively with the application, and the teacher of botany deals only with the principle. The teacher of agriculture should not hesitate to go over into purely scientific botany to review, or to teach again, if necessary, the fact or process which he is applying in his own work. On the other hand, the teacher of botany should not hesitate to carry the fact or principle he has just presented over into the field of agriculture and to apply it with sufficient detail to give to the student a definite understanding of its practical importance. An example will make my meaning clear. In the botany class the root systems of plants have been studied in detail. The students have become familiar with the form, structure, extent, and distribution of roots, and also with the origin, structure, distribution, and function of root hairs. After these facts are well in mind, then is the time for the teacher to connect these things with the agricultural practices concerning the structure, aeration, and water content of the soil. Likewise, when the teacher of agriculture deals, in detail, with soil physics, it is his opportunity to go into the field of scientific botany and to correlate his work on the soil with the structures and physiology of the plant root. This procedure, properly carried out by the teachers of botany and agriculture, would serve to bring these intimately related phases of biology into their proper relation to each other. If a teacher who is thoroughly prepared in botany as well as in agriculture teaches both lines of work, the problem of correlation, obviously, becomes easy.

There are other sides of this subject that are well worthy of consideration here, such as the proper preparation of the teacher, and the problem of the textbook, but I shall omit these and close with a very brief statement of my chief line of thought. 1. The central figure in scientific agriculture is the plant. 2. Botany is the science of the plant. 3. Scientific agriculture cannot be separated from the scientific study of the plant—that is, from botany. 4. The scientific study of principles and the practical application of these principles should form closely correlated courses for elementary students in agriculture. 5. The proper correlation of botany and agriculture is not a difficult problem if the teacher of botany has sympathy for, and a knowledge of, present-day agriculture, and if the teacher of agriculture is familiar with the fundamental structures and processes of the plant.

BUSINESS METHODS IN THE SELECTION OF LABORATORY APPARATUS.

By Ernest Carroll Faust,

Instructor in Zoology, University of Illinois.

This paper is written from the combined point of view of the teacher experienced in the use of physical and biological laboratory apparatus, and of one who, as a sometime employee of a large factory and jobbing house, has familiarized himself with the commercial handling of such apparatus. Some four thousand orders for laboratory equipment have come under the writer's attention. They comprise requisitions from all types of schools all over the United States and Canada, as well as certain ones for export shipment.

Firms which handle laboratory supplies for educational and commercial laboratories may be classed as manufacturers, large and small wholesale and retail jobbers, and local retailers. There is a certain advantage in purchasing certain articles from each of these houses. A purchase from the manufacturer insures fresh stock and prevents inferior substitutions. It also makes possible the ordering of piece apparatus from individual design for individual needs. The jobbing house handles the bulk of the trade, due to a greater variety of stock and to the fact that many manufacturers do not deal directly with the purchasing public. An order placed with a reliable jobber who carries a large stock is usually satisfactory. The local retailer in the city or small town may be relied on for small quantities of staple articles, and is a convenience at all times. Often he will save money and time. However, a large and comprehensive selection of equipment for all types of laboratories cannot be secured in entirety from any one of these concerns. For that reason some five or six firms in this country both manufacture certain articles for the trade and act in the capacity of large jobbing houses, carrying an ample stock from which the needs of the laboratory may be supplied. Some of these concerns manufacture physical apparatus and job biological and agricultural equipment. Others are specialists in optical goods. The writer knows of no firms which manufacture laboratory glassware or chemicals and job general laboratory equipment. From the double point of view from which the writer's experience has been secured, the most satisfactory concern for the buyer is one which specializes in the manufacture of general

physical apparatus for the laboratory, and jobs chemicals, glassware, biological and agricultural supplies.

Just as the firms handling laboratory apparatus differ in the amount and variety of stock which they have on hand, so the purchasers differ in their desires and needs. The selection of apparatus for laboratories in private and public secondary schools, normal schools and colleges, universities, and experimental stations, schools large and small, differs profoundly. On the whole it has been repeatedly observed that public high and normal schools have the most generous appropriations for their equipment. The colleges and universities are much more specific in their needs and much more exacting in requiring their orders to be filled to specifications. It must be admitted that selection of apparatus by high and normal schools often shows poor judgment. Is this due to the greater amount of money at their disposal? By far the most extensive and expensive equipment is shipped to agricultural laboratories in public high and normal schools.

In order that the reader may know something of the actual types of orders that are sent to the shipper, certain instances will be cited and certain errors in ordering pointed out.

The large supply houses publish comprehensive catalogs of their goods, assigning to each article a certain number. This number is usually a key to the position of the item in the stock room. Consequently an order is most satisfactorily filled which lists the articles desired in sequence order, with the addition of the name and special size of the item. Such an order saves time in the office, in the stock room, and in the shipping room. Where a chance assortment of items is listed in the invoice, errors may result at the hand of the clerk in the office or order room, or even by the checker or packer. Yet only a small minority of customers, perhaps ten per cent, list the items desired in systematic fashion.

Confusion in filling an order is frequently caused by lack of specification of items. Orders are frequently received by the jobber which would require an omniscient order clerk to interpret. "Rubber stoppers to fit test tubes" is a request found in certain orders where no test tubes are ordered. The customer may be aware that test tubes range in length from 1½ to 12 inches, and in diameter from ¼ to 1 inch; and that rubber stoppers are made solid, one-hole, or two-hole. More probably the buyer exhibited a lack of care in making out the order.

Again microscopic slides and covers are requested, without reference to size or shape. While the catalog may list the green flint slides with rough edges under a different number from the white slides with ground edges, and the square covers from the circles, the thickness of the former and the thickness and size of the latter may require specific notation. If no. 1 22mm. squares are wanted, and no. 2 18mm. squares are sent, the customer is dissatisfied, but whose fault is it, if the size has not been specified?

It is not advantageous to order a staple article in small quantities from a laboratory apparatus company when that article can be purchased from a local merchant. An order for "five pounds of flour," or a "a can of baking soda," a "spool of white thread," or "five yards of white cloth," or "a dozen thumb tacks," is an item that will often have to be provided for outside of the firm. The firm will oblige the customer in order to keep the trade, but will charge for the extra accommodation. A special messenger may have to be sent half-way across the city to procure the spool of thread. The "dozen thumb tacks" must be taken from a box of one hundred, and the time of the order picker is paid for by the customer. The writer realizes that many school directors will O. K. a bulk shipment from a single firm, while they will look askance at a large number of trivial requisitions. In such cases it is the duty of the teaching corps to educate the directors to see cost values.

At times, purchases of heavy articles of small value are made for long distance shipment. Sometimes the purchase is large enough to justify the item; more frequently it is not. The shipper is compelled to pack and label items according to prescribed regulations of the Interstate Commerce Commission. If "ten pounds of marble chips" or "Mason fruit jars" must be packed separately in order to conform to the rules laid down, the expense of packing and freighting is not justified.

The writer has attempted to place briefly before the laboratory teacher the "other man's point of view," and to show how certain methods of selection of apparatus will conserve time and money and eliminate error.

A SIMPLE RULE FOR EXTRACTING ANY ROOT OF A NUMBER.

By Otto Dunkel,
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In the November, 1916, issue of School Science and Mathematics, Mrs. M. W. Arleigh gave an interesting method for computing the square root of numbers. This method permits of an easy extension by means of which a good trial selection may be made for the following figure after a certain number of figures have been found. Thus in the identity used by Mrs. Arleigh $x^2—y^2=(x—y)\ (x+y)$, if we suppose that x is the root of the number, say of 5347, and y is the approximation already found, then $x—y$ is the correction to be added to this approximation in order to have the correct root. Since x and y do not differ greatly, $x^2—y^2=(x—y)2x$ approximately, and we find for $y=70$ that $x—y=447/140=3.+$. Hence 3 is a good number to try for the second figure. With this addition, however, the completed method does not differ essentially from the ordinary method.

Various methods, at least eight, have been devised for finding the square root of numbers, some of which are rather complicated and difficult in application. For finding a long string of the decimal figures one at a time, perhaps no method is more convenient and easily applied than Horner's Method, if the method of contracted division is used. But the theory of this process is not simple. There is one method, however, which is extremely simple in theory and application. It has been known for a long time and is really a modification of a much older method, called Newton's Method. The method has already been described by Professor E. R. Hedrick in his article, "Approximations and Approximation Processes," in the December, 1908, number of School Science and Mathematics, pages 749,750, but on account of its simplicity and value, and the fact that it seems to be so little known, I shall restate the rule and the principle of its working.

If we wish to find an approximation to $\sqrt{5}$, we first make what we regard as a good guess, say 2.5. We then test 2.5 by dividing 5 by it, for, if it is correct, then the quotient will be also 2.5; if it is too large, then the quotient will be too small, and conversely. In the two latter cases the correct root must lie between the divisor and quotient, and we select very naturally for the second approximation the number half way between the two, or their average. In this simple example the first computa-

tion can be made mentally, and we obtain 2.25 for the second approximation. We now repeat this process with 2.25 as a divisor, finding 2.2222. . as the quotient, and we see at once that the first two figures, 2.2, are correct. But the average 2.2361 is still better and, in fact, is correct as far as it goes. For most practical cases this would suffice, but a third application of the method would give nine correct decimals. In general, if a certain number of decimal figures are known to be correct, then the next step will give twice as many more correct decimals. When the exact quotient is used the average is always larger than the root.

This method is very conveniently used with a table of square roots. If, for example, we have a table giving square roots to four decimals, and we desire more, then a division and average will give the same figures in the table, except perhaps the last one, and twice as many more decimals. The process works whatever may be the first choice, but the better this choice the more rapid is the calculation.

It is easily seen how to extend the method to the extraction of any root. Thus to find $\sqrt[3]{9}$ we select a trial number, say 2, and to test it we divide 9 by its square. We obtain the quotient 2.26+, which shows just as before that 2 is too small and 2.26+ is too large. To make a good selection of a number between the two we again take the average of all the found factors of 9, i. e., of 2, 2, 2.26, and we obtain 2.08+. If we repeat the process with 2.08, the division soon tells us that these figures are correct, and again the average will be very much better. In this particular case the average in this second step yields a result correct in the first eight decimals.

DEEP SALT BED.

In Kansas a deep well struck rock salt at 690 feet below the surface and penetrated 600 feet of rock salt in beds from 5 to 60 feet thick, according to the United States Geological Survey, Department of the Interior. A large area in this state is underlain by salt, which is mined by many shafts and obtained by pumping brine. Drilling for oil in Texas and Louisiana has revealed the presence of tremendously thick deposits of rock salt at a depth of a few hundred feet. Thicknesses of 2,000 feet are common, and one drill hole passed through more than 3,000 feet of rock salt. Most of the salt made in Utah is produced by evaporating the water of Great Salt Lake, and in California by evaporating sea water. These sources are inexhaustible, and the limit of production by solar evaporation will therefore never be reached.

LOGARITHMS AND SOME OF THEIR APPLICATIONS FOR HIGH SCHOOL PUPILS.

By J. S. Counselman,
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Logarithms continues without doubt to be the most useful subject in elementary algebra. This is true in spite of the fact that the invention of such wonderful devices as the slide rule as well as the large amount of computation in all branches of engineering appearing in the form of handbooks, to say nothing of similar publications by construction companies, insurance companies, banks and other financial concerns, has somewhat diminished their practical value.

The teaching of logarithms in our modern high school is justified mainly on account of its practical value, therefore it does not seem advisable to carry the study of the theory too far. Dr. J. W. A. Young, a leading American authority on the teaching of mathematics, says, "The theory and practice of logarithms is naturally a part of the study of exponents and does more than anything else to give the subject of exponents a real meaning. It is a pity that the two subjects are ever divorced. Some drill in the manipulation of exponents is necessary, but the essence of these laws will be more deeply impressed by using them to abridge computation. It is only when thus used that the student is impressed with the great computational power gained by working with exponents."

Upon taking up the study of logarithms the following definition commonly in use should be clearly and definitely impressed. The logarithm of a number is the index of the power to which the base of the system must be raised to equal a given number. This can be done by having the pupil show that the log 1000 to the base 10 is 3.

After the student has been required to obtain by his previous study of exponents the logarithms of all numbers which are integral powers of 10 from 1000 to one ten-thousandth, he is then ready to be introduced to a table of logarithms. When a sufficient amount of drill has been given to insure a skilful use of the tables, the following equations, which express the fundamental principles involved in computation by logarithms, should be presented and simple proofs required or offered.

I. $\log pq = \log p + \log q.$

II. $\log \frac{p}{q} = \log p - \log q.$

III. $\log k^n = n \log k.$

} The base being understood.

As soon as the pupil has been given a sufficient understanding of these equations to enable him to interpret them he should be required to apply all the principles contained therein by writing the value of logvx in several equations similar to the following:

$$x = \frac{c^3\sqrt[3]{d}}{m^{\frac{1}{2}}\sqrt[5]{n}}.$$

In order to provide sufficient time for the little theory that has been outlined and thorough drill upon the tables with applications to follow, some of the following topics might be partially or toally omitted:

1. Complex cases of removal of parentheses.
2. Cube root of polynomials and numbers.
3. The Euclidean method of finding the H. C. F.
4. The more difficult problems in factoring.

The application of logarithms to the extraction of cube and fifth root impresses the student with their great usefulness, and furnishes a clear understanding of the relation between characteristic and mantissa, besides inuring a valuable drill upon the tables since both the logarithm of a number and the antilogarithm are to be found alternately. In teaching this application care should be used to select a list of numbers such that the characteristic of their logarithm shall alternate between positive and negative numbers.

The following formulas, $v = \pi r^2 a$, $v = \frac{4}{3}\pi r^3$, and $v = \frac{a^3}{12}\sqrt{2}$ expressing the volumes of a circular cylinder, sphere, and regular tetrahedron respectively, are well adapted to computation by logarithms, and should be familiar to the student on account of his previous study of solid geometry. Their solution by logarithms furnishes a valuable review of this important subject.

The application of logarithms to compound interest seldom fails to arouse the pupil's interest since it has to do with the earning power of money. After the following equations, which express the relation between principal, rate, time, and amount, have been explained to the pupil, he should be required to solve them by logarithms for each letter appearing in the formula.

$a = p(1+r)^n$ where interest is compounded annually.

$a = p\left(1+\frac{r}{2}\right)^{2n}$ where interest is compounded semiannually.

$a = p\left(1+\frac{r}{4}\right)^{4n}$ where interest is compounded quarterly.

Such problems occurring in everyday life as the following can be much more readily solved by logarithms than any method previously known to the student of elementary algebra.

Find the amount of $500 with interest compounded annually at six per cent, the time being five years, four months, and twenty-seven days.

Substitutions in the first of the above compound interest formulas should be made thus:

$$p = 500,\ r = 6\% = .06,\ n = 5+\frac{4}{12}+\frac{27}{360} = 5\frac{49}{120} \text{ or } \frac{649}{120}.$$

$$\text{Then } a = 500(1.06)^{\frac{649}{120}},\ \text{and } \log a = \log 500+\frac{649}{100}\log 1.06.$$

Hence a = $685.25.

A more interesting application of logarithms than any of the foregoing is the problem to be solved by the Farm Loan Bank in determining the equal, annual, semiannual, quarterly, and monthly payment necessary to pay off a loan with interest. The following table now in use by our Government gives the annual installment necessary to discharge a loan of $1,000 with interest, the number of years and rate of interest being indicated in the table.

FOR LOAN OF $1,000.

Years.	Five Per Cent.	Six Per Cent.
10	$129.50	$135.87
15	96.34	102.96
20	80.24	87.18
25	70.95	78.23
30	65.05	72.65
35	61.07	68.97
40	58.28	66.46

What more practical problem could be presented to the high school pupil than that worked out by our Government in the effort to assist the farmer upon whom we are all so dependent? This problem may be solved either by mathematical induction or as a geometric progression. Its partial solution by mathematical induction can be made clear to the average high school pupil if presented and solved in this manner: A man owes $\$p$ bearing simple interest at r per cent. He wishes to discharge both principal and interest by making three payments of $\$x$ each at the end of one, two, and three years. Solution: p times $r = pr$ = Interest for one year. $p + pr - x$ = Amount due and bearing interest after first payment. By repeating these calculations twice more, and remembering that debt should be discharged after three payments are made, we obtain in the above symbols:

$p+3pr+3pr^2+pr^3-r^2x-3rx-3x = 0,$

Hence $x = \dfrac{p(1+r)^3}{r^2+3r+3} = \dfrac{p(1+r)^3}{1/r[(1+r)^3-1]} = \dfrac{pr(1+r)^3}{(1+r)^3-1}.$

If 4 payments are made, $x = \dfrac{pr(1+r)^4}{(1+r)^4-1}.$

If (n) payments are made, $x = \dfrac{pr(1+r)^n}{(1+r)^n-1}.$

When applying this formula to a loan of \$1,000 bearing simple interest at six per cent, when payments are to be made at the end of each year for ten years, we should make the following substitutions: $p = 1000$, $r = 6\% = .06$, $n = 10$, the number of payments. Hence:

$x = \dfrac{1000(.06)(1.06)^{10}}{(1.06)^{10}-1}$. Now let $y = (1.06)^{10}$,

Then $\log y = 10 \log 1.06,$

$= .25310,$

and $y = 1.791.$

Then $x = \dfrac{1000(.06)(1.791)}{.791} = \$135.86.$

This formula is much better adapted to solution by logarithms when applied to this similar practical problem: A makes a loan of \$2,000 bearing simple interest at six per cent. He wishes to pay \$30 at the end of each month from date of loan until the debt with interest has been discharged. Find the number of payments he must make and the total amount paid out.

Since $x = \dfrac{pr(1+r)^n}{(1+r)^n-1}$, we have $(1+r)^n = \dfrac{x}{x-pr}$.

Let r = monthly rate $= \dfrac{.06}{12} = .005$ and $p = 2000.$

Then $(1.005)^n = \dfrac{30}{30-10} = \dfrac{3}{2}$, and $n \log 1.005 = \log 3 - \log 2.$

Therefore $n = 81.1014.$

Amount paid out $= 30(81.1014) = \$2,433.04.$

Some teachers in the past have been content to give the pupil a mere introduction to this subject. Now that the importance of algebra in our high school courses is being questioned, all should realize that a thorough working knowledge of such a vitally important topic as logarithms must be enforced if the subject is to maintain its former high rank in the curriculum

THE STATUS OF MATHEMATICS IN SECONDARY SCHOOLS[1].

By ALFRED DAVIS,

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Chairman of a Committee Appointed by the Mathematics Club of Chicago.

One might judge by the criticisms that come from certain quarters that algebra and geometry are in a precarious situation. Some would-be reformers would have us abandon the teaching of these subjects in high school in favor of what are said to be more useful subjects. Others would make them optional studies, or they would devitalize them by making them an easy and pleasant pastime for all who are required to take them. Still others would have us believe that the public is demanding such changes as these, and that it is only a matter of time until algebra and geometry as cultural studies are relegated to the scrap heap. It is a matter of considerable interest to know what persons outside the mathematical world, and who are qualified to speak of the subject, have to say as to the importance of mathematics in our scheme of education.

Our committee, representing the Chicago Mathematics Club, sent the following letter to prominent doctors, lawyers, merchants, bankers, etc., in the city of Chicago. We have avoided for the most part members of the teaching profession:

"The undersigned committee of the Chicago Mathematics Club, in cooperation with a National Committee of the Mathematical Association of America, is investigating the reasons for teaching mathematics in our secondary schools. We respectfully submit the following questions to you in order that we may have the benefit of your practical experience. Furthermore, your name will give to your answers a weight not attached to the opinions of persons less well known:

"1. Was the study of high school mathematics worth while to you? If so, why?
"2. Did its study contribute to your development anything which could not have been secured in equal degree from some other study which might have been substituted for it?
"3. In employing a young person or in advising him to follow your profession, what importance would you attach to a good school record in mathematics?
"4. In planning the secondary education of your son or daughter, would you include algebra and geometry? Why?
"5. Is a knowledge of algebra or geometry of any practical value in your business? If so in what way?
"6. Do you think algebra and geometry should be retained in our secondary schools?

"Your answers to these questions will be of great value to those who are striving to secure for our schools the best possible

[1]This part of the report was read before the Club at its regular October meeting, October 6, 1917.

course of study, and your assistance will be greatly appreciated by our committee."

Fifty-five replies have been received as follows:

Physicians and surgeons	7
Lawyers	12
Bankers	7
Merchants	4
Engineers	1
Clergymen	9
Manufacturers	2
Authors and newspaper writers	2
Social workers	1
Business managers	1
Economist	1
Real estate men	1
Broker	1
Typefounder	1
Railroad men	2
Secretaries	2
Printers	1

Answers to question 1:

Affirmative	43
Very emphatic	7
Reasons assigned:	
Mental training	27
Training in accuracy	5
Training in concentration	3
Pleasure	3
Practical value	2
Preparation for engineering	2
Preparation for physicians	3
Preparation for college	3
Negative	6
Reasons:	
Never used it	1
Of little value	1

Answers to question 2:

Affirmative	36
Very emphatic	9
Uncertain	8
Negative	6
(No reasons given, no comment.)	

Answers to question 3:

Great importance	19
Banker	3
Engineers	1
Physicians	2
Lawyers	3
Merchants	2
Clergymen	2
Brokers	1
Printers	1
Manufacturers	2
Railroad men	1
Considerable importance	21
Bankers	3
Physicians	2
Economists	1
Lawyers	7
Clergymen	4
Railroad men	1
Real estate men	1
Secretaries	1
Very little importance	2
Lawyer and social worker.	
No importance	3
Physicians	2
Typefounder	1

Answers to question 4:

Both	42
Algebra at least	3
Neither	2
Only as a prerequisite for professional work	3

Answers to question 5:

Affirmative	23
Physicians	3
1, Biological chemistry, microscopic study.	
1, Absolutely essential for science involved in medicine.	
1, Necessary in vital statistics.	
Lawyers	5
Engineers	1
Bankers	4
1, Investment mathematics.	
1, Refers to the graph as important.	
Writers	1
Mentions its value in allusion.	
Ministers	2
1, Logical help.	
1, Argument and persuasion.	
Real estate man	1
Manufacturers	2
Economists	1
Statistics and city planning.	
Printer	1
Railroad man	1
Negative	26
Bankers	3
Lawyers	5
Clergymen	5
Merchants	3
Physicians	4
Social worker	
Broker	
Typefounder	
Railroad man.	

Answers to question 6:

Affirmative	46
Very emphatic	14
For professional preparation only	2
Optional	2
Negative	2

The following additional information contained in the replies is of considerable interest:

Mr. John G. Shedd, President, Marshall Field and Company: "I firmly believe in the value of mental training derived from the study of mathematics, both the elementary and the higher branches. I know that training has been of especially great value to me, and the principles are constantly used in everyday business transactions. It seems to me that the aim of all branches of a school curriculum should be the development

of analytical and logical thinking by the student. Nothing in my judgment tends more to this than thorough training in mental and written mathematics."

Mr. C. F. Hoerr, President, Home Bank and Trust Company: "I should certainly consider it a serious mistake if algebra and geometry were not a part of the education of our children. I should want them to have algebra and geometry for a number of reasons:

"1. For the development of their reasoning and logical powers, and the concentration these subjects will demand.
"2. In case the children should want to major in any of the sciences.
"3. As a matter of general culture and training whether they desire to so major or not.

"Statistics are coming into their own, and the question of graphs is very important. We are making use of graphs in our business, and I feel that through this medium of presenting statistics we are better posted in our business."

Mr. G. M. Reynolds, President of the Continental and Commercial National Bank: "In planning the education of a child of my own I should insist upon algebra and geometry; for while only a few cases might occur in which the business man would make practical use of either, the mental training acquired in gaining a knowledge of algebra and geometry is of very great help in directing modern business, which is constantly becoming more complex by reason of increasing burdens—a condition which calls for the highest degree of preparation that the schools can give."

Mr. James B. Forgan, Ex-President, First National Bank, answers the questions as follows:

"1. Fifty years have passed since I studied mathematics in school. I have always thought that it, better than any other study developed my mind along the line of concentration of thought on problems confronting me. It was a study I liked and in which I excelled.

"2. Yes, the power of concentration, and I know of no other subject that if substituted for it, in my case, could have attained as good results.

"3. I would regard a good school record in mathematics as indicating a mind trained to concentration of thought on problems until they are solved.

"4. Yes.

"5. Arithmetic sufficient.

"6. I do."

Rabbi Emil G. Hirsch answers as follows:

"1. It was. I had, even as a lad, a knack for languages. Be-

fore I was twelve years of age I spoke four and read eight. Mathematics provided for me the balance wheel.

"2. It did. It taught me to reason in abstract relations.

"3. Soundness of judgment, I hold,is apt to be better developed, and sequence of thought as well.

"4. I should include both. Educationally both are effective. Practical advantages—perhaps the discovery of mathematical bent in him.

"5. Not directly but indirectly it is—reasons given above.

"6. I do most emphatically. High schools are not factories turning out, one tracked minds."

Mr. H. H. Kennedy, lawyer, Moses, Rosenthal and Kennedy, answers as follows:

"1. Unqualifiedly yes. It is my judgment that the study of mathematics very materially assists in developing the reasoning faculties of the mind, and powers of anaylsis.

"2. Yes, because I do not believe there is any study taught in the high school that would tend to develop in an equal degree the faculties of the mind referred to. Logic, in my judgment, is merely a higher form of mathematics; a person who is a good mathematician is invariably a good logician.

"3. In advising a young man to enter upon the profession of the law, I would urge him to take up mathematics above all other subjects in the high school, since I believe that the primary essential to qualify a person to successfully practice law is the mental faculty of reasoning and the power of analysis. It also tends to develop the powers of abstract thought to a much higher degree than any other subject taught in the high school and especially the powers of concentration essential to success in any profession, and more particularly the law. Should a young man come to me with an exceptionally good record in mathematics, I should conclude therefrom that he had a well developed mind, and was especially fitted to practice law, for the ability to reason well and the power to concentrate are evidence of a good legal mind.

"4. Yes, I would most certainly include these two studies in planning for the secondary education of my son; indeed, I pursued this very course, and in connection with his studies at the University High School and Princeton University I urged upon him the importance of these subjects, and he pursued this course, his intention being to enter later upon a legal education.

"5. A lawyer enjoys a particular advantage if he is well

equipped in algebra and geometry; he finds himself brought into all forms of intellectual inquiry which require abstract thinking; familiarity with these subjects comes into play every single day; and the principles of geometry are the foundation of logic.

"6. By all means. The science of algebra deals with representations of facts and permits the easier handling of them by the mind. A person well versed in algebra is especially qualified to detach himself from the facts of life in such a way as to enable him to reach conclusions free from bias or personal interest. It is unquestionably true that a lawyer who is a good mathematician is almost invariably a lawyer of ability, because he has a trained mind that enables him to stand upon his feet and reason well."

Thomas E. Donnelley, President, R. R. Donnelley and Sons Company, Director of the Chicago Directory Company, answers as follows:

"1. Yes, it trained me to think along logical lines and it gave me a clear idea of the necessity of being 100 per cent accurate.

"2. Yes, there is no study that could possibly take its place.

"3. I would not employ him unless he was good at mathematics.

"4. Yes, both, and trigonometry as well. It is the science of facts as they are. Anyone who doesn't understand these studies lacks an appreciation that things happen because they must.

"5. Yes, it gives one the ability to solve a problem.

"6. Yes. Who on earth thinks otherwise? It is the basis of our whole industrial life."

Judge E. O. Brown of the Appellate Court answers as follows:

"1. It was. I cannot for myself conceive why mathematical truths (which seem to me to be the thoughts of God before time was) should not be worth any man's study.

"2. It did.

"3. I should advise any young person to study mathematics and to obtain as good a school record as he could in them.

"4. I would—and did with my three sons and two daughters. Because I consider them very important branches of knowledge and very stimulating in intellectual pursuits.

"5. I hardly know what meaning to attach to 'practical.' I should be less competent in every way without such knowledge.

"6. I certainly do. If they are to be eliminated I do not know what should be retained."

Dr. James B. Herrick, physician: "A progressive physician today *must* know physics, chemistry, physiology, physical chemistry, etc. Without the elements of mathematics such knowledge is impossible."

Mr. Marquis Eaton, attorney: "These studies (algebra and geometry) tend, in my opinion, to develop the power of analysis, which power lies at the threshold of success in every profession, notably the legal profession."

Mr. James E. Otis, President, Western Trust and Savings Bank, "I consider the study of high school mathematics as a necessary part of a high school education. In so far as I am concerned, my knowledge of algebra, geometry and higher mathematics frequently enables me to analyze problems which come before me. It is the training of the young mind in the study of algebra which I consider of greatest importance and not the practical use he can make of the science in later life. In so far as geometry is concerned, questions are constantly arising where I find my knowledge of geometry most helpful. I feel so strongly on the subject that I should consider the dropping of algebra and gometry in our secondary schools as a very serious mistake"

Mr. S. M. Hastings, President, Computing Scales Company of America: "My personal business experience has taught me that mathematics, algebra and geometry are important, and in my opinion they should be retained in our schools. With a knowledge of these, one is better fitted to cope with the business problems.

"As we become a greater world power and our foreign business expands, the need of every possible mental equipment will be more and more in evidence."

Mr. C. A. Creider, Secretary to Edward B. Butler of Butler Brothers: "Anyone who has been able to compass the subjects of algebra and geometry is by very nature of his training equipped to comprehend a problem or to arrive at a solution thereof much more readily than the fellow who has not had the training referred to. In other words, even a private secretary, who might be expected to have very little to do with the principles of these two studies, finds it much easier to fill his position having gone through the mental exercise of study of these two subjects."

Mr. C. S. Cutting, attorney, Holt, Cutting and Sidley: "The study of high school mathematics was worth while to me for this reason, among others, that the cultivation of the habit of

mathematical methods of thought not only fixed my knowledge of the so-called practical mathematics of the grammar school, but made all operations of like nature, whether strictly mathematical or otherwise, easier. . . . It is not usually possible to shirk work (as a student) in mathematics (it is therefore desirable in the course of study). . . . We use geometry in the examination of titles to real estate, in the investigation of plats and in many other relations where mensuration of both lines and angles must be considered. In my opinion, however, this is the smallest part of the benefit derived from the study of these subjects. . . . I believe that the emasculation of a literary college course by omitting the classics is an educational mistake which would be equaled by omitting the mathematics. My experience teaches me that the man who knows a few things well is better educated than the one who knows many things indifferently."

Mr. James K. Ingalls, President, Western Heater Despatch: "High school mathematics taught me system, to be accurate, to have confidence in my conclusions, and accustomed me to abstract reasoning."

Mr. Granger Farwell broker: "I employ algebraic and geometrical calculations in business and many times without knowing that I specifically do so."

Miss Harriet Vittum, social worker, says:

"2. Yes, I disliked it so heartily I needed to *have* to do it.

"6. Yes, as general mental discipline if not to fill specific needs."

Rev. James G. K. McClure President, McCormick Theological Seminary, "I am accustomed to say that the classics have done more to prepare me for my life than any other study or studies. The drill in Euclid at Yale was very disciplinary."

Rev. M. P. Boynton, Woodlawn Baptist Church: "The practical geometry that I learned in my father's carpenter shop, and which was based on the steel square of the workman, has been of greatest practical use to me. Though I had no occasion to use these rules for many years, I was delighted when in building my summer home, and needing the rules for cutting and fitting the rafters and other timbers to find that these principles which I actually worked out as a boy freely came back to me. I believe that this is nature's great law and that we retain only such knowledge as we are able to make real use of."

Dr. J. Clarence Webster, physician, says that in planning

the education of a son or daughter he would not include algebra or geometry, "unless these subjects were directly related to their professional work. . . . I think they are as useless as Latin and Greek and should not be taught to the great majority."

A prominent clergyman of the city writes: "Even the admitted value of geometry in training the logical faculties has to be discounted because the faculty is there developed in a field entirely apart from any of the practical problems of life, and its general cultural value is therefore indirect and remote. This is not so much a matter of judgment on my part as a matter of practical experience. My judgment is that algebra and geometry are quite unnecessary as a part of *general education* and that for purposes of general culture other subjects are much more useful in the curriculum of secondary education. Yet it is perfectly clear that engineering and architecture, not to mention certain branches of physics and astronomy, absolutely require a knowledge of algebra and geometry.

"My daughter, now twenty-one years of age, had a distinct gift for languages and history. Mathematics of any kind were exceedingly difficult for her and even untiring industry and excessive efforts barely sufficed to secure a passing mark. Yet algebra was a required study and graduation from high school impossible without a reasonably satisfactory record in this study. She will never make any use of algebra and she has bitter memories connected with its study, together with a rankling sense of injustice in a system which requires a given standard in this useless subject and allows no substitutes in the requirements for graduation."

This is probably as representative a group of persons as could be selected. A larger group would not be likely to change results greatly. They are all busy men of affairs. That they should answer so fully is significant of the importance they attach to such matters. About 90 per cent answer favorably to the importance of mathematics in secondary schools, some of them emphatically so. This is an overwhelming majority. An election with such a majority would be called "a landslide." While there are many factors which may enter to make the opinion of a single individual, or even of a small minority, of doubtful value, great importance must be attached to the opinion of such a majority. The members of such a group cannot all be biased or prejudiced; they cannot all be out of date in such matters, or be unacquainted with the trend of affairs in

the educational world. The fact that they are successful men precludes any such notion. Some of them are giants in the business world and in other fields—men to whom we look for leadership.

However, the opinion of a minority, or even of a single individual, is not a negligible matter. These frequently suggest important lines for improvement, or they raise an issue and put to the test things that have come to us through tradition. When we recognize a fallacy in the argument of an opponent we are reassured in the position we hold. Those who have opposed the teaching of mathematics in high schools—where they have expressed themselves beyond the mere answer "no"—seem to think of mathematics only as a tool. To them its only value seems to be the direct application in the sciences or in the doing of the world's work. This is a mistake, as is shown by the answers to questions one and five. Question one, which is considered a referring to cultural values, has an overwhelming majority in the affirmative; while question five, which represents the utility values, has a small negative majority. Evidently the direct application of mathematics to other fields is of secondary importance. The chief values are culture and mental discipline, training in logical and abstract thinking, the cultivation of the power of concentration, and the acquiring of speed and accuracy in our mental activities. However, this matter will be treated at greater length in the more complete report to be made later by this committee.

President Butler of Columbia University says in *Educational Review*, September, 1917: "No educational instruments have yet been found that, in disciplinary value, are equal to Greek, Latin, and mathematics. The descriptive and experimental sciences cannot do it—or at least they have not done it—and the same is true of the newer subjects of study that are humorously if roughly, classified together as 'unnatural sciences'—economics, sociology, and the like."

An investigation, as reported by Mr. Harris Hancock in *School and Society*, June 19, 1915, was carried out recently in Cincinnati. Of 105 prominent persons in the city, and 99 outside the city, consulted with reference to the question, "What course of study should be taken by a boy who is entering high school?" 167 answered that they would require mathematics, 18 would require either mathematics or the classics, and 12 would make mathematics elective. This experiment carried

on with a larger group more widely scattered gives approximately the same majority in favor of mathematics as is shown in our experiment. The following came with the replies:

Hon. Chas. Theodore Greve, of the Cincinnati Law School: "I have specialized in history and economics, but they can never take the place of classics or mathematics. Both are essential and there can be no possible substitute for either. . . . These two subjects are the essential groundwork of education that is to be of value for any subsequent career, professional, scientific, business or mechanical."

Hon. Roscoe Pound, of the Harvard Law School: "The two things which appear to me to be required of secondary education are, linguistic training . . . and some sort of training which will form settled mental habits of accuracy and thoroughness during the student's formative period. I believe mathematics will achieve the latter result as nothing else may. Personally I never liked mathematics; but they were valuable, not for what I remembered, but because I was compelled to see that two and two make four, instead of presenting plausible arguments that it might be otherwise."

Mathematics is, however, an important study not for the boy alone but for the girl as well. Since the girls of today will be the mothers of tomorrow, and so will bear the greater share of responsibility in the education of the coming generation, for this reason, if for no other, algebra and geometry ought to be a part of the education of every girl.

Margaretta Tuttle, an author, and also of Cincinnati, says in *Good Housekeeping*, September, 1917, that the old line education, even though requiring effort that is not always pleasant, is best. "Will-power continues to be the great need of all who hope to grow and be of use. And it continues to develop only by use.

"Marianne hates solid geometry. Marianne's mother does not see why her daughter has to waste a whole year on something she can never by any possibility use. Marianne is literary. Oh, no! Literary ability and mathematical ability rarely go together. Marianne, who is eighteen, and who knows a little about the lives of writers and nothing at all about engineers, will tell you so. But all the same, after Marianne, by the sweat of her brow, has worked out these different problems, she will have formed the habit of not flinching from thinking things out—one of the most necessary habits for a literary person and for any woman.

"Women do not always do it, nor men either. It is the thinking of things out that steadies the world. It is the confronting of a problem with the intent of solving it after you have seen both sides of it that makes you a real help in a world of unsolved problems. You cannot write a good story, short or long, without a problem in it that has to be thought out and then demonstrated. Many a literary person living a meager life on small success, unable to solve the problem of why it is so meager, needs a little mathematical training. Many a mother struggling with the problem of her child's food, and wishing she had taken dietetics instead of piano lessons, needs the mathematical touch —the ability first to recognize a problem when she sees it, then to attack it without worry, to bring to its solution all the like problems that have been previously solved, all the axioms and theorems that actually apply to it, and then to come to a conclusion and to stick to it because it has been demonstrated. *Quod erat demonstrandum!* The woman who has learned the full power of that phrase has learned to handle facts."

These testimonies and the results of these investigations make it evident that algebra and geometry are *not* so much rubbish to be thrown out at the back door as quickly as possible, as some would have us think. The number of persons who object to the requiring of mathematics in our high schools is relatively a small minority, which, in its efforts to be heard, sometimes makes a noise all out of proportion to its numbers. The professional, the business, and the industrial worlds, at least, demand for the present, and will demand for years to come, that algebra and geometry be retained as required studies in the secondary schools of our country; and this notwithstanding the efforts of educational theorists and would-be reformers to the contrary. Would it not be time and effort better spent if the destructionists were to aim at the perfecting of the subject matter, and to the improvement of its teaching?

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HOW SCHOOL GARDENS TEND TO DIRECT A NATURAL COURSE IN BOTANY.

By Genevieve Monsch,
Froebel School, Gary, Ind.

I speak of this as a natural course because, unlike most other courses in botany, this one seemed to have unfolded itself gradually from day to day so that the subject-matter as well as the sequence of the work were largely determined by the progress of the more practical outside garden work, and by the demand for information by the boys and girls who were engaged in the work. It certainly grew independently of other courses of study and of textbooks—for we used none whatsoever—and it certainly developed quite independently of the teacher, who, when she had planned a definite series of lessons on soils was switched unexpectedly to herbaceous perennials, annuals, etc., and, at a time when she was least expecting to take up the most difficult of all subjects, namely, plant processes, she suddenly found herself in the midst of such problems with the most wide-awake girls and boys carrying her still deeper and deeper into the discussions of plant-physiology until, lo and behold, they were quite ably dealing with questions of photosynthesis, digestion and assimilation—and the teacher had, in several instances at least, discovered, through the class, a much simpler approach to the subject than any that had ever been suggested before. The class was not required to write up any notes of their work, and except in the work connected with the morphology of the flower, no drawings were required. We used no textbooks and no reference books in class, although government bulletins, seed catalogs and garden guides were constantly in demand and in use.

The course as I have outlined it here was developed with a class of seventh grade girls and boys who came to me in separate sections for only ten weeks, at the very end of the school year. Thus, only fifty hours of class time was given to this course, although the individual members of the class were permitted to work in the garden at odd times—and they did find much time to work there, in large numbers daily, by giving up either a gymnasium or an auditorium or a lunch period, or by begging off from some more formal work.

The foundation of the course was work out of doors, frequently in the school gardens, but occasionally in our school park, and on two occasions in the adjoining swamps and woods.

First Week.

A. Investigation of Gardens:
  I. How are they laid out?
    1. Bird's-eye view from school windows.
    2. Blue prints of whole school garden plot on wall.
    3. Blue prints of individual plots.
    4. Excursions into the garden.
  II. What do they contain?
    1. Hardy annuals—lettuce, portulaca, Mexican fire bush.
    2. Biennials—parsnip, carrots, etc.
    3. Perennials—Dutch bulls, honeysuckle, lilac, etc.
  III. What are they going to offer us?
    1. Individual plots (two), selected and accurately measured.
    2. Class cold-frames visited and discussed.
    3. Soil:
      a. Soil composition—straw, manure, lumps of clay, sand, rocks, sandstone, quartz, etc., decaying vegetable matter.
      b. Subsoil—sand.
      c. Moisture content.
      d. Compost-heap.
    4. Animals in soil.
B. Individual Vegetable Plots:
  I. Measured carefully.
  II. Diagram to scale.
  III. Individual selection of vegetables from seed catalogs.
  IV. Cultural directions studied for spacing rows in diagrams.

Note: Diagrams of individual plots must be completed at the end of the first week.

First Week.

During the first week of this course we did little outside garden work although we were kept more than busy with our investigations, our seed catalogs, our garden diagrams, etc., as shown by the outline for the first week's work. (By the way, these outlines were made at the close of each week while those made at the beginning have been long since discarded as useless.) The class encountered a steady downpour of rain on the very first day of the course, which, however, proved fortunate, inasmuch as it took us to the windows and to the general diagrams of the garden and to discussions of gardens in general *before* we started any actual garden work. I had planned an interesting series of work on soils for our first real excursion into the garden, but the class chased wildly to the beds of tulips, daffodils and hyacinths which were just beginning to peep above the ground. At least a dozen questions were eagerly asked (and answered) before these children showed any inclination to be turned aside. This gave me my cue, and I really found it the simplest matter in the world to explain annuals, biennials, perennials, etc., and to find them most anxiously searching in all directions for more and more types within the garden walls to illustrate each term. They asked for the names of everything and knitted their brows in order to help to fix them all in their

memories and they repeated them to each other again and again The next day we had very little difficulty in getting the following outline from the class, although I purposely included again such new words as ampelopsis, clematis, etc., which they had forgotten overnight.

Blackboard Outline.

Our First Visit to the School Garden.

I. Hardy Annuals—lettuce, wild cucumber, Mexican fire bush, portulaca, morning-glory.
II. Biennials—parsley, parsnip, lunaria.
III. Perennials:
1. Woody perennials—rose, privet, hydrangea, lilac, willow, one peach tree.
2. Woody vines—honeysuckle, bitter sweet (celastrum), ampelopsis, wistaria, clematis, rose, Virginia creeper, etc.
3. Herbaceous perennials:
a. Bulbs—tulips, daffodils, hyacinths, etc.
b. Rootstocks, tubers, etc.—ferns, violets, lilies-of-the-valley, various weeds and peony, cannas and dasheens in cold-frames.

Note: Diagrams of individual plots must be accurately finished at end of first week.

Their vegetable plots were next selected and measured and careful diagrams made to scale, *after* they had each decided for themselves just what they were to grow. Seed catalogs were studied and were borrowed to be taken home to be discussed with the family, and the all-important matter of their lives became, for that week at least, a garden diagram to represent their individual tastes and the method of planting. By the end of the first week most of the diagrams were accurately made and our real work in the gardens was beginning. I am not going to discuss in this article the flower plots—for each pupil of course had two plots, each being about four by seventeen feet, one for vegetables and one for flowers. Everyone had to begin with his vegetable plot but just as soon as this was laid out and planted he could begin with his flower garden. There was no one in the class who did not finish both plots before school closed.

Second Week.

A. Restaking Individual Plots.
B. Preparation of Seed Bed:
I. Adding barnyard manure (why?).
II. Deep spading (why?).
III. Pulverizing with hoe and rake (why?).
IV. Add sand (why?).
C. Fertilizers:
I. Natural manures:
1. Animal fertilizers—bone meal, barnyard manure.
2. Green manures—legumes. Do all plants have tubercles on their roots?
II. Commercial fertilizers—from animals, plants or minerals:
1. Steamed bone (phosphoric acid).
2. Dried blood (nitrogen compound).
3. Wood ashes (potash).

4. Ammonium sulphate (nitrogen compound).
5. German Kainit (potash).
6. Acid phosphate (phosphoric acid).

Note. There are usually only three most necessary ingredients that must be supplied: (a) nitrogen compounds; (b) potash; (c) phosphoric acid. One ton barnyard manure contains: Nitrogen compounds, 10 lbs.; potassium, 8 lbs.; phosphorus, 2 1-2 lbs.; lime, magnesia, etc.

III. Discussion of rotation of crops.

Note: Why is barnyard manure one of the very best fertilizers?

Second Week.

By the time these children had worked with seed catalogs and cultural directions for a few days, they became exceedingly familiar with such terms as annual, biennial, etc., and with tubers, bulbs (sets of onions), etc. Moreover, questions of soil (light soil, heavy soil, loose soil, loam, clay, etc.) were constantly arising, and fertilizers and soil covers were beginning to puzzle their little brains. They were grateful to have an hour indoors to clear up a great deal of this work towards the end of a delightful week in the garden which, however, had required heavy muscular work in the preparation of the soil for a seed bed. Some of these children had added more barnyard manure to their plots and all of them had spaded it under and pulverized their soil. In the laboratory we had kept large glass jars filled with different commercial fertilizers. These were not only labeled but they also contained the names of the principal ingredients which they could supply for the plant, and each member of the class was required to make a list such as you see under "Commercial Fertilizers" in the outline for the second week's work. In this way they were made to feel that the three most important ingredients to be supplied to the soil are nitrogen compounds, potash, and phosphoric acid—and the value of barnyard manure was forcibly brought out by the diagram which they made. Lime was also discussed, and green manures became of so much interest to these children that they were constantly sacrificing their beans and peas for the sake of a little research on their own part. I would like to say that this seventh grade class was allowed the use of the compound microscope on several occasions and that this was one. It was a matter of no little surprise to me to find that they could handle these instruments as skillfully as high school pupils, and that they could interpret what they saw just as well. Their curiosity, however, was keener and their spontaneity and enthusiasm much greater.

Third Week.

A. Planting Seeds According to Diagrams *Exactly*.
B. Work in Perennial Beds:

I. Remove covers of leaves, straw, manure.
II. Tillage of perennial beds in the school park as well as in the garden. (Value of tillage?)

C. Germination of Vegetable Seeds:
I. Requirements for germination:
1. Air.
2. Water (daily).
3. Warmth.
4. Soil (?).
II. Observations connected with germination:
1. Some rows have germinated. Why?
2. Some rows have not germinated. Why not?
3. Seeds cause soil to crack. Cause?
4. Arch to hypocotyl (or none).
5. Cotyledons—one or two? Color? Size? Position?
6. Plumules.
7. Seed coats above or below the soil?
8. Cotyledons above or below the ground?
9. One seed coat or more?
10. Cotyledons shrivelling.
11. Cotyledons turning green.
12. Why do cotyledons shrivel? (Food in seed? Uses of food? Kinds of food, etc.)

Note: Child in the garden always includes "soil" as one of necessary requirements for germination. As far as he has been able to discover up to this point, it is, and that is the reason it has crept into this diagram.

Third Week.

This is the week when enthusiasm certainly does run high, and when the skillful teacher will keep it high, and see that it is quietly and unsuspectingly directed into the right channels. Their seeds are germinating, some of them at least, and the teacher must be sure to see that they are discovering, each for himself, the cracking of the soil, the arch to the hypocotyl, the cotyledons and plumules and seed coats and a hundred other things, in the height of their eagerness. She must be the spirit behind them that keeps them eagerly watching, and she must keep them puzzled and interested over a hundred things that are happening or not happening. "Why" should constantly be heard in the garden and if the child ever fails to ask it, the teacher must.

Fourth Week.

A. Seeds:
I. Structure of seed:
1. Seed-coats.
2. Food in seeds:
a. Starch or sugar.
b. Oils.
c. Proteids.
3. Embryo:
a. Root.
b. Stem.
c. One or two seed leaves.
d. Plumules.
II. Monocotyledons or dicotyledons.
III. Uses of food in seed:

1. Growth.
2. Energy.
3. Repair.

Note: Continue observations in gardens and pigeonhole information as germination progresses.

Fourth Week.

During the fourth week we directed our discussions to the seed. These children had eagerly watched and helped hundreds of seeds to grow and were quite familiar by this time with the parts of the seeds. There remained only one thing more for the teacher to do; that was, to systematize their knowledge and to review or to add such technical terms as proteids, etc. Technical terms were avoided just as far as possible in this whole course. Since we used no text, it was easier to avoid mere terms, too. Instead of embryo, for instance, we used "baby plant in the seed." Instead of cotyledons, we used "seed leaves," and "first real leaves" instead of plumules.

Fifth Week.

Plant Processes:

A. Review Food Storage in Seeds and Uses of such Foods in Plants.
B. Name other Food Storage Places (roots, stems, leaves, flowers, bulbs, tubers, etc.)
C. Photosynthesis:
    I. Gross structure of leaf:
        1. Stalk.
        2. Blade:
            a. Green tissue.
            b. Skin.
            c. Veins.
    II. Experiment: Starch = $C+H_2O$.
    III. Experiment: Conduction.
    IV. Experiment: Solution (sugar and starch).
    V. Discussion: Conduction, assimilation, respiration, storage, transpiration, reproduction, death.
    VI. Experiment to show transpiration.

Fifth Week.

Now, you may wonder how we suddenly jumped from germination to photosynthesis but by good luck an accidental question directed our work along this line the first time I gave any kind of an organized garden course, and it fitted in so easily that I have put it right about here at other times. One of these lads one day accidentally discovered a huge plant growing in a ridiculously small pot of soil and he at once demanded to know "how such a little bit of soil could ever produce such a big plant?" It was a golden opportunity to discuss starch-making and other physiological processes. By weighing the plant as it stood in its pot (17 lbs.) and then by weighing a similar pot filled with soil but without a plant (12 lbs.), there was clearly a

gain of five pounds of matter which could not possibly have come from the soil. Where could this extra gain have come from? Where indeed but from the water and the air! It is not difficult to show (by burning) that plants are largely composed of carbon (plus water); and by heating starch in a test-tube, that starch is carbon plus water, and so I found that it was not beyond the comprehension of these children to understand that green tissues in plants make starch out of the carbon in the carbon dioxide of the air and out of the water from the soil which the roots send up. Just a step further, and we had worked out the subjects of conduction, solution, digestion, assimilation, etc. I took great pains to keep this subject ever before their attention in one way or another until the very close of school and there were many opportunities for doing so—the cotyledons turning green and then dropping off *after* the plumules are able to manufacture starch; the storage of food in seeds, tubers, bulbs, tap roots, etc., the original source of food, and the kind of food stored up in their garden crops which they themselves were appropriating as a supply for their own bodies, the demand for increasing leaf-surface on the part of the plant, etc.

Sixth Week.

A. Where Do Seeds (and Fruits) Come From?
   1. Locate immature fruit and seeds in tulip, hyacinth, narcissus, violets, pansies, willow, lilac, fruit-blossoms, iris, sweet peas, bush-honeysuckle.
   2. Also find pollen boxes in each flower.

B. Morphology of Flowers:
   1. Seed case and seeds.
   2. Pollen boxes (and pollen).
   3. Petals.
   4. Sepals.

C. Functions of Each Part of Flower.

D. Analyze Flowers, as Many as Possible:
   1. Hyacinth.
   2. Tulip.
   3. Indian puccoon.
   4. Lupine or pea or locust.
   5. Geranium (wild or cultivated).
   6. Violet.
   7. Iris.

E. Discuss Pollination.

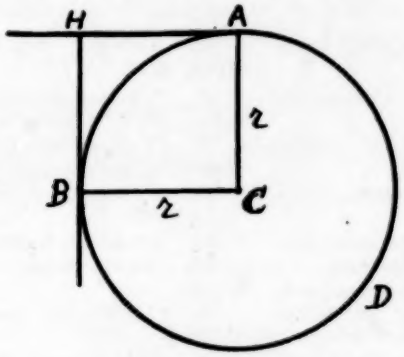
F. Discuss Fertilization in Flowers (Egg, Embryo, etc.).

(To be Continued.)

FORMULA FOR CENTRIFUGAL FORCE.

By Roswell Parish,
Mechanic Arts High School, Boston, Retired.

Is it possible to satisfy a beginner that this formula is true without resorting to the method of limits? The following is submitted (with more or less of diffidence) with a view to criticism.



Let us suppose a mass m to be projected from A in the direction AH with a velocity v, and at the same time to be drawn toward C by a constant force f just sufficient to keep it in the circular path ABD. It is required to find the value of this centripetal force f and of the equal and opposite resistance—the centrifugal force.

Evidently the velocity will remain unchanged, since the force toward C acts always at right angles to the path and neither helps nor hinders the forward motion.

Now when the body starts from A it has motion in the direction AH. When it arrives at B, 90° from A, it has lost all motion in that direction and has acquired an equal amount in the direction HB, perpendicular to AH. In other words, the centripetal force has been employed equally in destroying the initial and producing the final motion of the mass m. The result is the same as if half that force $f/2$ acting through AH (or r) had done $mv^2/2$ units of work in destroying the original motion, and then the other half acting through HB (or r) had done the same amount of work in communicating the final motion. In either case, since as already proved $FS = MV^2/2$, $(f/2)r = mv^2/2$, whence $f = mv^2/r$.

The formula for acceleration follows readily, for
$f = ma = mv^2/r$, whence $a = v^2/r$.

FORESTS AND LUMBERING REFERENCES

PREPARED BY W. M. GREGORY,
Normal School, Cleveland, Ohio.

The following list of references upon forests and lumbering has been prepared for the help of students and teachers of commercial and industrial geography, agriculture, and manual training. The list includes the sources that ought to be used when these subjects are well taught, and the star (*) indicates that the book has been used with junior high school students.

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THE GRAPH OF ax^2+bx+c.

BY J. L. PATTERSON,
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The solution of $ax^2+bx+c=0$ gives $x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}=\frac{-b}{2a}\pm\frac{\sqrt{b^2-4ac}}{2a}=\frac{-b}{2a}\pm k$, say. It is evident from the latter form that $\frac{-b}{2a}$ is the *axis* of the graph and if $\frac{-b}{2a}$ be substituted for x in the equation $ax^2+bx+c=y$, the value of y resulting will be the *lowest* point of the graph. (If the first term is negative, the value of y will be the *highest* point of the graph.) The point in which the graph cuts the axis of Y may be found, as usual, by making $x=0$ and the symmetrical point is at once determined. Thus we know the *axis*, the lowest (or highest) point and two other points, which will give the graph roughly by a minute's work. If the graph cuts the axis of X (that is, if there are real roots, not equal), two other points are readily determined by the solution of the equation.

Take for example, $2x^2-5x+8=0$. $x=\frac{-b}{2a}\pm k=\frac{5}{4}\pm k$.

$\therefore x=\frac{5}{4}$ is the axis and if $\frac{5}{4}$ be substituted for x in $2x^2-5x+8=y$, $y=4\frac{7}{8}$, the lowest point. Again, if $x=0$, $y=8$ and the opposite symmetrical point is $\frac{5}{4}$ to the right of the axis.

A METHOD OF TEACHING IONIZATION.

By Leroy F. Swift,

Head of the Science Department, Worcester Academy, Worcester, Mass.

Did you ever succeed in teaching a class ionization? How often do you receive the answer, "Ionization is the breaking up of the molecules of a substance upon the passage of a current of electricity through the solution"? *Why*? Is your method of approaching this subject sane and logical?

Most introductions to the subject begin with experiments showing that certain solutions conduct the electric current. What does a boy see in such an experiment? *A most fascinating electrical experiment.* What impression of ionization can he get from this experiment? Electricity, it is true, is a point of contact with his previous knowledge, and the only one, but its inherent fascination and the fact that the desired results are invisible—explained only by theory—ought to make us look for a better introductory experiment for this topic.

The existence of ions can be proved more directly by a series of experiments with copper salts. Make saturated solutions of cupric bromide, cupric chloride, cupric nitrate, and cupric sulphate. Note the color of each carefully. They are all different and very similar to the crystallized salt—dark brown, green, dark blue, and blue, respectively. These are the colors of the molecules, for they are the colors of the masses. Now dilute each of these solutions by pouring a small quantity into a large volume of water. The four solutions now have the same blue color. What has happened? They must contain something in common. What? Copper. Yes, but in what form? Evidently not the insoluble, solid copper. Again, the color indicates that the copper in these solutions is in a different form than in the saturated solutions. In the latter, the smallest particle is the molecule of the salt—the copper bromide molecule for instance. The copper, there, is an inherent part of the molecule. Diluting these solutions with water separates the copper from the bromine. The copper, in this new form, since it imparts a bluish color to the solutions, is blue. The copper in this new form is called the copper ion, the bromine, the bromine ion, etc. The separation of the molecules into ions, by the water or other dissociating liquids, is called ionization or electrolytic dissociation.

The hydrogen ion of acids and the hydroxyl ion of bases may

be shown by treating dilute solutions of either with the proper indicator—litmus, methyl orange, or phenolphthalein.

After using the above experiments to show the presence of the particles called ions, present the more difficult physical evidence for ionization—conductivity, rise of boiling points, depression of the freezing points, osmotic pressure, and electrolysis.

The conductivity experiments are now in order, for we wish the terms electrolyte and nonelectrolyte, and more concise definitions of ions and ionization. A solution that will show directly the atoms ionized is preferable. With platinum or carbon electrodes, in series with an incandescent lamp, pass a current of the proper strength through a solution of cupric bromide. A deposit of copper forms on the negative electrode, and bromine appears at the positive electrode. Repeat, using other solutions—salts, acids, and bases. In all cases the filament of the lamp glows, showing conductivity. Now use solutions of sugar, alcohol, and distilled water. These solutions, since the filament does not glow, are nonconductors or nonelectrolytes. Now present the theory. The latter solutions do not conduct the current because their molecules do not break up into ions. The ions of the former act like bodies charged with electricity—a static charge. They are attracted or repelled by the electrodes. The copper ion, for instance, always goes to the same electrode—the negative one. Hence the copper ion is the copper atom bearing a positive charge of electricity. The bromine ion must, then, bear a negative charge. The nonconducting class of solutions allows no current to flow; therefore, they have no such charged particles. A more complete definition of the ion, then, is an atom, or a group of atoms acting like a single atom, bearing a charge of electricity. The influence of this charge is responsible for the new properties. Further study of such experiments shows that the molecules of the electrolytes break up, on solution, into two parts, one carrying a positive charge of electricity, and the other an equivalent charge of negative electricity.

All of these solutions which conduct the electric current—electrolytes—show, when compared with nonelectrolytes of equivalent molecular concentration, a rise in the osmotic pressure and the boiling points of just twice as much as the nonelectrolytes. Again, the freezing points of solutions of the electrolytes show a depression twice as great as that of the non-

electrolytes of equivalent concentration. Why? Explain this by means of the kinetic theory. Pressures and also boiling points and freezing points depend on the number of impacts per second—the number of molecules striking per second. Since these pressure changes in the electrolytes are twice as great as those in the nonelectrolytes, the solutions of the former must contain twice as many particles. Since the molecular concentration is the same, each contains the same number of molecules. Hence each molecule of the electrolyte must have broken up, on solution, into two parts. This would account for the increases in the pressures noted in the solutions called electrolytes.

Ionization is greater in dilute solutions. Ostwald gives an experiment that shows this very clearly. Add a few drops of ammonium hydroxide to an alcoholic solution of phenolphthalein. There is no evidence of the hydroxyl ion. Add water slowly, and the characteristic color soon appears. (The color will disappear if enough alcohol is added.) Since this color reaction is a test for the hydroxyl ion, hydroxyl ions are more abundant in dilute solutions.

I often feel that we do not emphasize the ionic theory enough to make it of real use in our teaching. I believe that we should write more ionic equations and make insistent use of its teachings in neutralization and electrolysis.

In many of these suggestions I have only indicated a method of procedure, but I trust that I have made clear the fact that we must and can make a more constant application of the psychological principle of apperception.

REPLY TO "ELIMINATOR OF WASTE IN THE HIGH SCHOOL."

By Jessie D. Brakensiek,
High School, Quincy, Ill.

I have read with much interest an article in the November, 1917, number of School Science and Mathematics, entitled, "Chemistry as an Eliminator of Waste in the High School." I feel that the author is so greatly in error in many of the things he says against other subjects in the curriculum that he needs to be corrected. His main attack is directed against geometry, Latin, and modern languages; his plea is made in behalf of chemistry. I do not wish to attack chemistry, for I believe that it is a subject worthy of a prominent place in the curriculum, and

that the writer, carried away by his own enthusiasm, has merely claimed too much for his subject. Had he not recommended it as a panacea, one would be more ready to accept it for its real worth. I feel that a plea should be made for the other subjects which he has chosen to attack. Let us take the author's own line of argument and see how it may be applied to the despised geometry and language.

"Educators agree that there are five main types of learning: (1) Acquiring motor skill. (2) Associating symbols and meanings. (3) Acquiring skill in reflective thinking. (4) Acquiring habits of enjoyment. (5) Acquiring skill in expression."

I shall endeavor to show that geometry and language are not so lacking in these virtues as our author would have us believe, and I shall not throw mud at the subject of chemistry in order to prove my point.

First, *acquiring motor skill.* The author evidently has forgotten that a great deal of construction work is given in geometry, involving the use of ruler, compass, and pencil. Drawing on blackboard and paper is an everyday occurrence. That motor dexterity is actually taught is proved by a comparison of drawings made by beginners in a geometry course with those made by more advanced pupils. Certainly the evidence which can be produced defending geometry on this score is fully as conclusive to an impartial observer as the breakage charges of an average chemistry student. If anyone thinks that geometry offers little training in acquiring motor skill, let him try to make a drawing of the "devil's coffin," or to construct models of the regular polyhedrons, or to inscribe a regular pentadecagon in a circle and actually get a fifteen-sided figure. As for the languages, no plea can be made under this head. Their value lies in other directions.

Second, *associating symbols and meanings.* Has the author forgotten that geometry is full of symbols, that the laws of mensuration are here developed, and then put into formulas for ready reference and use? As he has already said in regard to chemistry, I shall say in regard to geometry: "Witness the multiplicity of symbols and formulae," and I shall be fully as correct as he. When it comes to the case of languages, let me quote again. In reference to associating symbols and meanings, he says: "It has been stated that this type of learning is furnished most by modern languages." This idea he has wisely not attempted to disprove. That the word, modern, can justly

be eliminated from the quotation any fair-minded person must admit.

Third, *acquiring skill in reflective thinking.* The writer admits that training in reflective thinking is the real value of geometry, but says that "this end can be just as well served by other courses." Later he says, "The training in thinking acquired in geometry is generally found to be of no use in other subjects requiring thought." Suppose we admit the truth of this statement. Will we not have to explain how training acquired in chemistry will be of use in other subjects? Why will thinking "about the behavior of gases, about evaporation, about ignition, about temperature, about solution, about concentration effects, etc.," be a more beneficial training than thinking about the congruence of triangles, the use of geometric figures in construction and in design, or the conic sections? Why are the subjects that the author suggests more provocative of thought than the ones I suggest? And why will training in thinking acquired in chemistry pass over so readily into some other unconnected field of thought, if the training offered by geometry will be of little or no avail? If I admit that the training in thinking acquired in geometry will serve only in the mathematical field, will he not also have to admit that the training acquired in chemistry will serve only in the scientific field?

Why does he say nothing of the value of languages in training pupils to think? Does he not know that there is no work in school so difficult for the scatter-brained as languages, that success in language work depends upon clear and logical thinking?

Fourth, *acquiring habits of enjoyment.* Here again let me quote: "Training for the enjoyment of leisure time is one of the ultimate ends of education." Agreed. I hope, however, that he does not mean to argue here that chemistry surpasses languages in this respect, with the testimony of the educated the world over so overwhelmingly in favor of the classics. How many read chemistry for pleasure? Any more, think you, than get pleasure out of their geometry? Do your meals taste any better for knowing that now you are eating proteid and carbohydrates instead of meat and bread? Does H_2O slack your thirst any better than a draught from the fountain which sets you to repeating, "O fons Bandusiae, splendidior vitro"? Does an article on soap-making, say, give you more enjoyment than a study of a magnificent building whose architecture is made

intelligible through the study of classical lore and of geometry? To my mind, language has much the best of the argument here, and geometry can at least hold its own with chemistry.

Fifth, *skill in expression*. Here the writer says: "I have resorted to the following scheme." Is not that a confession that chemistry is not wonderfully adapted to developing skill in expression? Does a Latin teacher have to "resort to a scheme" to secure this end? If the writer thinks that translation work does not foster skill in expression, let him try to give a vigorous translation of an oration against Cataline. By the time he has accomplished it he will have a wholesome respect for Cicero's command of language, for he will find his own vocabulary taxed to the utmost. In the case of geometry, I would not claim for it greater possibilities in developing skill of expression than I would for chemistry—nor less. In both, the field for expression is limited to a clear, concise statement of fact.

In closing, the author makes a plea for the practical worth of chemistry. I am perfectly willing to concede that he is right I am glad the chemist does so much for the farmer, and the manufacturer, and for all of us by making the world a healthful and pleasant place of abode. I thank him for his gorgeous dyes, his cleansing soap, and even for his powder and explosives, now that the main business of this country is war I honor him for his worthy achievements. But are these of more worth than the dams, which furnish power and make possible the reclamation of the desert, or than the Panama Canal? Are these more valuable than the building of bridges and ships, of churches and skyscrapers, of schools and homes, which need the principles of geometry for their successful design and construction? It is true that the majority of those who take geometry will never be engineers or architects Is it not also true that many take chemistry who will never be chemists? Shall we teach geometry only to those who will need it? And, if so, how are we to select them? Are we so omniscient that we can select the chosen few who are to be our engineers and architects? And, if we could, would we be wise to do so? Bah, the idea smacks of German efficiency, of which the world has already had an overdose. Why not also acknowledge the debt we owe to Latin and other languages? The author would do well to peruse Miss Frances Sabin's book, *The Relation of Latin to Practical Life*, particularly pages 58 to 62, and most particularly page 61. For fear he may not do so, let me reproduce the last three lines of page 61:

"Professor Bauer, the distinguished chemist of Vienna, once said: 'Give me a student who has been taught his Latin grammar and I will answer for his chemistry.'" Let the writer try this test on his own class. See if those who have studied their Latin the most diligently are not as a rule good in their chemistry.

Moreover, the author is himself under a greater debt to the classics than he realizes. His article abounds in Latin English and in some English Latin. Witness, he says formulae, when he might have gotten further from the despised subject by saying formulas. How can the author be a really up-to-date chemist without a knowledge of French and German? I have been told that much which a chemist should know of French and German research is not found in translation.

Through enthusiasm for one's own subject, one must not fall into the error of overlooking the worth of another's. All are good. Some appeal to one, some to another. The public schools should make their appeal to all. Therefore, may chemistry flourish, but permit geometry and language to occupy their rightful place. Live and let live.

HINTS FOR COLLECTING BOTANICAL AND ZOOLOGICAL MATERIAL.

By John L. Dahl,
Highland Park, Mich.

Botanical and zoological material can easily be collected and kept on hand for use by schools in any locality, rural and metropolitan alike, such collections making teacher and class independent of season, imperfect illustrations, and distant supply houses. This being the case, less stress should be laid on so-called museum specimens, and greater stress on material available at the threshhold of almost every school. Many additions can be made by individual teachers to the suggestions given below.

Botanical Material.

Dry fruits et al. as follows: ash, elm, milkweed, dandelion, maple (several forms), ailanthus, catalpa, cucumber tree, chestnut burrs, horse-chestnut burrs; pine cones and those of other evergreens; acorns; various cultivated forms as morning-glory, balsam, poppy, nasturtium, etc.; seeds of all kinds from several successive years (label according to year collected, as 1915-1916-1917-1918), excellent for trying viability tests; desiccated twigs to show morphology of tendrils, spines, thorns,

etc., dried specimens of all unusual conditions in nature, such as cross sections to show knots in wood, grafted stems, characteristics of bark of all available trees, etc.; cornstalks.[1]

Fleshy fruits et al. (these may be preserved in four per cent formalin as a rule): thorn apples, osage orange, bean pods and pea pods, rose hips, cucumbers whole and in section, boiled corn cobs for extracting easily the embryo from the "seed"; stages in the development of the apple fruit, for example, from the bud to the blossom and the very small fruit, then various stages in the development of the fruit, and sections of the mature fruit; cultivated fruits of all kinds, such as cherry, plum, peach, currant, strawberry, etc.; specimens of seedlings in various stages of development; fleshy roots, whole and in section.

Rare specimens (if fleshy, preserved in formalin): pitcher plants; petals of the water lily to show the transition from petal to stamen structures; pistils of the double cherry blossom to show the leaf-like character of the pistil; sprouted potato showing the development of small potatoes from the parent; etc.

Zoological Material.

Special equipment, of course, is necessary to take care of living material in the classroom. For preserved material the hints for collecting botanical materials will suggest what sort of zoological specimens to collect (four per cent formalin may be used as a rule for preserving proper zoological material).

Several stages in the life of the grasshopper, showing incomplete metamorphosis; abundance of crayfish material, showing varying sizes, also female with eggs attached; dried material, showing metamorphosis of various kinds of insects; insect collections, showing mimicry, protective resemblance, etc.; earthworms; habitations of various hymenoptera, made of paper, mud, leaf, and stem tissues; cocoons of various kinds; collections of birds' eggs and stuffed birds (and other animals) obtained under proper circumstances, etc., etc.

Methods of Preservation.

Mice, insects, and dust are factors destructive of biological material but are easily guarded against. Ordinary preserving jars are cheap, transparent, easily stored, and mouse-and-dust proof. No rubber rings should be used for dry material, as a circulation of air and desiccation is desirable. Material preserved in formalin should be made air-tight to guard against evaporation.

[1] Many specimens may be preserved both in a dry and a fleshy condition.

A SCIENCE CLUB IN A HIGH SCHOOL.

By Louis C. Feldmann,
University of Wisconsin, Madison, Wis.

Every high school in which seventy-five or more pupils are enrolled ought to have a science club. While attending high school the boy passes through what G. Stanley Hall calls "The Gang Age." It is during this period that much permanent damage to the boy's character can be done, for at this time he chooses his associates. These will exert their good or bad influence over him as the case may be. On the make-up of the gang and its moral standard will depend the developing or the suppressing of such traits as good-fellowship and a desire to do right. Since the boy's later character depends to such an extent on his associates, the greatest aid that can be given him is the choosing of proper companions. The club with its selected membership exercises this function.

For the girl such a club is no less important; first of all, on account of the influence for good that she, under proper guidance, can exert on the boys, her fellow members. Then as for herself this association will develop in her the spirit of cooperation. This last-mentioned trait was formerly considered as desirable for men only, but with the growing complexity of economic life this spirit is no less essential for women.

Aside from the power of developing character which such a club can be made to exercise, both boys and girls will have instilled in them a love for nature and the great outdoors. These two features, if properly rooted, will remain with them throughout life. They will be no mean sources of pleasure and health during their active years, and an enjoyable pastime for old age. If education is a preparation for life, then this club is a necessary part of education.

We have noticed the necessity of a club for the boy to carry his primitive instincts into worthy channels. The girl needs a club to round out her character and aid her rapidly developing womanhood. The natural inclinations of both call for it; as well as the need of making wholesome recreation a hobby to be indulged in throughout life. But on whom falls the lot of organizing and directing such an undertaking? It is extra-curricular and yet highly educational. I should answer that it is the biology teacher's duty, for his field is attractive enough to arouse the dormant interests of the pupils. Further, the biology teacher will not only feel as though he has accomplished some

educational work, but he will draw around himself a circle of interested boys and girls who will be able to discuss intelligently with him his special problems.

There is another good result which the teacher can consider as having accomplished. I here refer to the community spirit of the boys and girls. After a successful year as a member of a biology club, the interest in parks, flowers, and the general beauty of the surroundings will be appreciated far more. They will make attempts to keep the neighborhood neat, and if possible they will cultivate plants or shrubbery in bare places.

Now by organizing and directing I do not mean that the teacher should immediately after entering upon his duties send a notice to the assembly room stating that a meeting will be held at such a time for the purpose of forming a science club. Let the teacher first be successful in his classroom, and then after he has created the proper spirit in his students let them at his suggestion form a club. The official work of such a club ought to be in the hands of the students, except perhaps the position of critic. This the teacher could advantageously fill, for it would give him a place from which he could properly guide the actions of the club without making it seem as though he were controlling the activities, and thus kill the interest of the members.

To provide suitable programs in order to keep up the interest and induce proper activities on the part of the members is always a serious problem. On the nature of the program presented will depend the success and life of the club.

Various types of programs can be undertaken. One of these is to provide each member with a copy of a certain book, and then take up one chapter at each meeting and discuss it. As an aid to the discussion certain pupils can be asked to prepare short papers on certain phases of the subjects taken up in the chapter. Personally, I see no interest in such a meeting for our high school pupils. To them this would merely be another class with all the accompanying drudgery.

A more interesting program would be to study natural objects in their proper environment. This would mean field trips with the accompanying joys for the pupils. Of course these trips could be undertaken only during the fall and spring. During the winter other activities would have to be indulged in, and I think it would be well worth the while of the students if during the trips in the fall they were to pick up and preserve certain

objects that they might happen upon, and then during the winter months study and discuss them. If a museum is to be found in the city, several meetings could profitably be held there. Then, too, programs could be arranged by having members give papers; talks, often illustrated, by members of the faculty; and addresses by outsiders who are experts in their own lines.

In the winter months, if the interest begins to fail, the scope of the club could properly be widened somewhat so as to include the fields of physics, chemistry, and geography to some extent. A feature of a few programs could be the visiting of some of the local industrial plants. This ought to be both profitable and enjoyable. Often a whole program could be taken up with one subject. At some meeting, for example, certain students could present the subject of carbonic acid. A tank of gas could be bought, and many freezing experiments could be performed and their biological significance pointed out.

Membership is rather a delicate proposition, for if the rules are too stringent no students will join; and, on the other hand, if too loose the members will lose interest and gradually withdraw. Certain requirements ought, however, to be insisted on, and among these are (1) a mark of 85 in one subject, (2) an interest in science, (3) a readiness to attend all the meetings, and (4) a willingness to take part in the programs when called upon.

The dues ought to be fifteen or twenty-five cents a semester, which will be more than enough to meet all ordinary expenses and pay for one or two sociable events to be arranged for during the school year to break the monotony of a too scientific atmosphere.

ANNOUNCEMENT FROM THE UNIVERSITY OF MICHIGAN.

INTRODUCTORY SCIENCE—One-half or one unit. Instruction in Introductory Science should precede all other courses in science and should preferably be given in the ninth grade.

The aim of this course should be to enable the student to interpret his environment and his relation to it. Teachers of Introductory Science are expected to give instruction also in one of the other sciences and to have had adequate preparation in one physical and one biological science. The ground to be covered by the course should be largely determined by local conditions.

A committee of representatives from the Education and the Science men of the University of Michigan has been appointed to draw up a statement of the preparation advised for teachers of general science.

RESEARCH IN CHEMISTRY.

Conducted by B. S. Hopkins.
University of Illinois, Urbana.

It will be the object of this department to present each month the very latest results of investigations in the pedagogy of chemistry, to bring to the teacher those new and progressive ideas which will enable him to keep abreast of the times. Suggestions and contributions should be sent to Dr. B. S. Hopkins, University of Illinois, Urbana, Ill.

THE PRESENT OPPORTUNITY IN CHEMISTRY.[1]

By Roger Adams,[2]
Assistant Professor of Organic Chemistry, University of Illinois.

A few years ago the public in this country scarcely knew what chemistry or what a chemist was. When this war started, however, a change suddenly took place. The chemist is now one of the most significant individuals in the majority of manufacturing plants, as well as of the most vital importance to the war. In England at Oxford University the study of chemistry used to be known popularly as the "Study of the Stinks," but now this science at that same university is certainly being shown its due respect.

I believe that the present opportunity of the chemist may best be pointed out to you by reviewing briefly the chemical development made in this country by the American chemists since the summer of 1914. It is needless to mention what a monopoly Germany had on chemicals before the war started, a monopoly not only in organic chemicals, but to a considerable extent in inorganic chemicals. As soon as the supply was cut off it was not a difficult matter for American manufacturers to increase the output of most of those substances which had already been manufactured, and develop the processes for other inorganic chemicals of a similar nature, so that within a year most of the inorganic substances purchasable before the war could be procured in this country. It was more difficult, however, to fill

[1]Address delivered before the High School Conference at the University of Illinois, November 23, 1917.

[2]Dr. Adams has taken a prominent part in the effort to meet the American demand for organic chemicals whose supply has been cut off by the war. He has entire charge of the commercial manufacture of organic chemicals at the University of Illinois and is a member of a committee appointed by the American Chemical Society to arrange for cooperation among the large institutions in supplying organic compounds to educational and technical laboratories. He is also a member of a committee authorized by the National Council of Defense to consider problems in connection with organic chemicals and synthetic drugs.

the increased demand for sulphuric and nitric acids which were most urgently needed in enormous amounts for the manufacture of explosives. Few people realize the large quantities of sulphuric acid needed in a country like the United States; in fact it has often been said that the civilization of a nation can be told by its output of this acid. In spite of Germany's prestige in chemistry, it was not more than ten years ago that the Badische Anilin & Soda Fabrik paid a very large sum of money to American manufacturers to find out the best apparatus for the making of sulphuric acid. The large increase in the production of nitric acid involved more complications, for the salt peter necessary had to be imported from Chile. Fortunately, this importation could be increased in a comparatively short time until the output of nitric acid was large enough to supply the demand. With the entrance of the United States into the war, the Government considered the problem of nitric acid much more seriously because it was necessary to rely entirely upon Chile for the raw materials needed for producing this acid. If Germany had not solved the problem of synthesizing nitric acid without the use of Chile salt peter, she could not have continued the war for a year with the supply of materials on hand in that country in 1914. Last April a committee of prominent American chemists was appointed to investigate the situation in the United States and to make recommendations to Congress. These recommendations were passed, and $35,000,000 was appropriated for purchasing a reserve supply of sodium nitrate, while $20,000,000 was set aside for the development of the general problems of fixation of nitrogen from the air. Of these fixation methods, there are three which have been used commercially in the European countries up to the present time: the arc process of combining directly nitrogen and oxygen to form the oxides of nitrogen; the cyanamide process consisting of a direct combination of calcium carbide and nitrogen to form calcium cyanamide; the Haber process, a direct combination of nitrogen and hydrogen in the presence of a catalyzer to form ammonia. By the first process, nitrates can be formed by absorbing the oxides of nitrogen in alkali. In the second, the calcium cyanamide is treated with steam to yield ammonia, which can then be oxidized quantitatively to nitric acid in the presence of air and a catalytic agent. In the same way the ammonia obtained in the Haber process may be converted to nitric acid. The first method is practicable only

where a large amount of water power is available, consequently the latter two are those now being used in Germany. The General Chemical Company of this country nearly five years ago foresaw the necessity of synthesizing nitric acid from the air, and set their chemical experts to work on the problem. A process was developed which is now ready to be put into commercial operation, a process far superior to any that has been used in Germany or other countries. It consists in making ammonia, then oxidizing it to the acid. Although similar to the Haber process in that ammonia is produced by the direct combination of nitrogen and hydrogen in the presence of a catalyzer, it has the distinct advantages of using much lower temperatures, obtaining double the yields, and involving simpler mechanical apparatus. Of the $20,000,000 appropriated, the committee recommended that $3,500,000 be devoted to a plant to be erected in Sheffield, Ala., capable of producing 60,000 pounds of ammonia per day by the General Chemical Company's process and of converting this ammonia to nitric acid. Much smaller sums were set aside for the further study of other methods, excluding the arc method, which seemed impracticable at present. The most promising of these is that developed by Professor Bucher of Brown University during the last ten years, consisting of the reaction of sodium carbonate, coal, and nitrogen in the presence of iron as a catalyzer to form sodium cyanide, which by boiling with caustic soda gives ammonia and sodium formate. The ammonia can then be oxidized to nitric acid. The prospects are bright, therefore, that within a year the United States will be independent of foreign lands for their nitric acid.

Of the other inorganic chemicals, the lack of potassium salts was most seriously felt. Formerly, these had been imported almost exclusively from the Stassfurt beds of Germany, so that to supply the needs of the United States it became necessary to seek other sources. The kelp industry developed to an enormous extent, especially along the California coast; the extraction of potassium from alunite and other potassium-containing silicates met with more or less success; the extraction from beet sugar residues became a large business; the extraction from various natural brines and salts increased remarkably. Searles Lake in California alone is said to contain ten million tons of potassium salts, and the process of separation from the other salts is already a practical proposition. Finally, many plants

for the extraction of potassium from wood ashes have been started, and in the Middle Western States huge amounts of corn cobs are burned daily for the large percentage of potassium that the ashes contain. To show the marked increase in the potassium industry, a few figures may be given. In 1915, the output of the various potassium compounds corresponded to a thousand tons of potassium oxide; in 1916 to ten thousand tons of potassium oxide; and the indications are that in 1917 the output will correspond to between fifteen thousand and twenty thousand tons. About forty per cent has come from the natural salts and brines, forty per cent from kelp, and twenty per cent from the other sources mentioned above. Thus the potassium difficulty is being satisfactorily solved.

Although much smaller in volume, the lack of an organic chemical industry was much more keenly felt by the general public. When a man's new black overcoat or a lady's black spring hat turned green in the course of a few weeks, that particular person began to realize that something should be done in regard to the dyestuff industry. In the same way, when thousands of persons could not purchase the medicinals they formerly used, these individuals began to feel that this country needed something more than a chain of drug stores. The organic chemicals may be divided into four groups, explosives, dyes, drugs and photographical developers, and fancy organic chemicals.

It is hardly necessary to mention the explosive industry. It was a strong one in this country before the war, and a comparison of the exports in 1914 with those of 1917 will serve to make one understand how rapidly it has expanded. In 1914, $6,000,000 worth were exported; in 1917, the figure will reach $1,240,000,000.

As for the dyes, the seeming slowness in their manufacture during the first year of the war may be excused when it is realized that the most fundamental substances, as well as the intermediate compounds, had to be manufactured before the finished products could be made. Germany had such a complete monopoly in this line of chemicals that the commonest substances were not produced in this country. When it became necessary, however, to develop this industry, which consisted before the war of five American concerns of comparatively small size that did some manufacturing but were for the most part importers of foreign dyestuffs, the manufacturers came to the front.

At present, there are 150 firms producing either intermediate products or finished dyes, and of these at least fifteen are very large corporations. Already, about eighty per cent of all the dyestuffs which were imported before the war are now being manufactured in this country, and it is probable that half of the remaining twenty per cent will be on the market within the next year. The final ten per cent are very complex in nature, difficult to prepare, and needed only in small amounts. When it is brought to one's attention that for some of the common cotton dyes it requires more than twenty distinct processes in order to get the finished product, it is remarkable that the development has been as rapid as it has. It is true that high prices still persist, so that only the more expensive goods contain the better dyes, but this is simply because the manufacturer has invested large amounts of money, and as long as possible intends to make a big profit. Moreover, he prefers to work out at this time the preparation of new dyestuffs rather than spend his energy in developing to a greater extent the ones which he has already produced successfully in a commercial way. In 1913, $350,000 worth of dyes were made in this country; in 1917, $12,000,000 worth, and of this $12,000,000 worth, a very appreciable proportion has been exported. Last July alone, $500,000 worth were shipped abroad, chiefly to Argentine, Brazil, Japan, and British India.

One often hears it asked why American manufacturers did not enter this field before the war. The reply has been that it was due to the fact that we did not have good chemists in this country. That is a great mistake. The dye industry was not taken up for two reasons. First, no really large concern cared to go into this work, and smaller concerns were unable to compete with the German industrial methods. One specific example may be cited. About six or eight years ago, a concern in the East built a $200,000 plant for the production of aniline. At that time, aniline sold for twelve cents a pound and these particular manufacturers were able to produce it at 11 cents. Not long after their product was on the market, the imported material suddenly dropped to between nine cents and ten cents, and upon investigation it was shown that the German manufacturers were selling below cost. This was continued for nearly a year and a half until it was necessary for the American dealers to drop the business. About three months after that date the price of the imported material rose to thirteen cents a pound.

The question as to why a larger manufacturer did not take up the work may be easily answered. Although the business was extremely important, it was not large enough to attract the American investor, because the labor and experimentation costs were great, and the returns would have been comparatively small, particularly on account of the keen competition which was sure to come from Germany. The following illustration will serve to bring out this point. All of the various color industries in Germany together manufactured over twelve hundred products and controlled probably eighty per cent of the world's markets. They paid in 1913 dividends to the amount of $13,000,000. In the same year the Ford Motor Car Company, which produced only one article, earned four times the amount of all these German color industries together, and paid at the same time three times the wages. Many more instances of this same kind might be given. The dye industry in this country is now here to stay, however. Not long ago I was told by the head of a big factory that they were producing many of the chemicals which were needed in very large amounts at a cost thirty per cent to forty per cent below what these substances sold for before the war, in spite of the fact that their raw materials were much more expensive. With a reasonable protection by the United States Government, the indications are that the American dye industry in the next decade will become second to none in the world.

The photographic developers have gradually been manufactured at the same time as the dyestuffs, so I will pass over this interesting group of substances and speak briefly of the drugs. Even before the summer of 1914 this country produced and exported large amounts of natural medicinals, substances extracted from plants, as quinine, strychnine, etc. But comparatively few synthetic drugs, those made up in the laboratory from simple organic substances, were produced in this country. At the present time, however, practically all the common ones are made and even exported in large quantities. The synthetic drug industry is a much newer one than the dyestuff, and many of the important drugs are still under the patent laws, and these patents are held chiefly by alien enemies. Since some of these substances are of extreme importance, the Government, a short time ago, passed a bill which would allow a reliable American manufacturer to obtain a license from the Federal Trade Commission to produce these substances provided

he pay into the United States Treasury five per cent of the gross proceeds from his sales. This arrangement is to proceed until a year after the war is completed, six months from which time the patentee must sue the American dealer for his royalty. A court is then to decide whether the five per cent is large enough or too large, and the exact amount to be paid to the patentee will be settled. This bill, however, does not suit the American concerns, and a number of the larger ones have been unwilling to take up the manufacture of these patented drugs under such conditions. The American Government is willing to license more than one concern for the manufacture of these drugs, and therefore there will be competition, not only at the present time, but even keener competition with the German producers after the war. Although the bill has been passed for five or six weeks, comparatively few applications for licenses have been made, and many of these have come from concerns controlled by German capital. A few American manufacturers will no doubt undertake the production of certain of these patented drugs for which the demand is extremely large and where the indications are that the necessary investments will be paid for and big profits made before the war is over. In this group may be mentioned especially salvarsan, needed so extensively in the army, and novocaine, a local anaesthetic of the greatest value. There were some hundred or more other drugs manufactured almost exclusively in Germany and sold in this country before the war which had only a very specific use and consequently for the most part only small sales. Many of these are still under the patent laws. The remainder are not, but it will be a long time before American concerns will undertake the synthesis of these substances. The demand is small, the manufacture difficult, and in most cases nearly as good substitutes of much simpler nature are on the market. The drug industry in this country at present, although not as satisfactory as that of the dyes, is being rapidly developed, and it will not be long before the United States will hold its own in this branch of chemistry.

The last class of organic substances is the fancy organic chemical reagents. These include not only the materials badly needed for scientific research, but also those almost indispensable for analytical work, food testing, etc., as dimethyl glyoxime for the quantitative determination of nickel, cupferron for the separation of iron and copper, phenyl hydrazine for sugar

separations, and many others. Considerable quantities of these compounds were on hand in this country when the war broke out, held chiefly by university laboratories and distributing concerns. By careful conservation on the part of the universities and greatly advanced prices on the part of the distributing houses, a serious lack of these reagents was not felt until this last year. The manufacturers have not attempted, and will not at present attempt, to produce these compounds, on account of the comparatively small demand, on account of the skilled chemists that it needs for this work, and on account of the very small profits involved. The University of Illinois undertook the work of preparing many of these substances which were needed most. Since the 1st of June a number of graduate students have been employed in this laboratory and have made up to the present time over one hundred different compounds which had not been manufactured in this country before and which were badly needed by laboratories all over the country. In this work special attention has been paid to developing the processes from the laboratory scale of 25 or 50 grams to a scale of 1 or 2 pounds, and thus it has been possible to give the men a training not to be obtained in any other way in a university, a training of the kind most needed now in the chemical industry. At the same time, valuable service has been rendered to scientific, technical, and Government laboratories throughout the country. Moreover, the students have been paid enough so that their living expenses would be covered. Amounts of these reagents varying from a few grams of certain ones to nearly a hundred pounds of others have been made and sent away, and the business already has amounted to between $7,000 and $8,000, which is large if it be considered that not a single piece of apparatus has been used which was not formerly at hand, and not a single man doing the work has had any training outside the university. At the present time the cooperation of other large universities is being sought so that more ground may be covered. It is hoped to form an organization for the manufacture of this class of substances which will continue not only until the war ends, but until such a time as a large American manufacturer will undertake the work, not for profit, but to help the United States become independent of foreign laboratories.

One other phase of chemistry should not be overlooked at the present time, the chemistry of gas warfare. This can hardly be called an industry unless it is determined by the amount of

money expended for its development. England is spending $125,000 a day simply for its study, and that sum does not include the cost of manufacture of the material actually used in the fighting. In February, 1915, the first attacks were made with chlorine and bromine. Four days after that attack, the English had provided one million troops in France with protective masks. Since that time, the intensive study of poisonous gases and liquids and the protection therefrom has been the serious problem of the leading chemists in the various warring nations. Last spring a large per cent of all the shells fired on the Western front were liquid shells, and that number is increasing continually. The use of gases has been given up to a considerable extent as they are too volatile and soon blown away. What is sought for now especially are liquids, boiling between 100° and 200°, tear-producing and poisonous. These will often remain on the ground for days and prevent the soldiers from remaining there except when wearing their masks. The first attack at Verdun was made with a new liquid which was not absorbed by French gas masks, and it is reported that the original attack on the Italian front a few weeks ago was started with a liquid which had not hitherto been used. The extreme importance of this warfare can immediately be seen, for if it were possible to obtain a poisonous liquid or gas not absorbed by the enemies' masks, and which could be produced and used in large amounts, the chances of breaking through a line not supported by many reserves would be great. There are, at Washington, at the present time, between two and three hundred chemists working continually on the development of different phases of this warfare, from the offensive side as well as the defensive side. An interesting point in connection with this work is the great secrecy needed, since the secret service of the various nations is most active and effective. Not many months ago, it was reported that the Germans used a colorless, odorless liquid or gas which when breathed gradually poisoned the soldiers, caused blindness in the course of a few days, and subsequent death. This report was true, but before the material was used on the Western front the English Secret Service had found out what it was, how much the Germans were capable of manufacturing, had obtained blue prints of the mechanical apparatus, and these were in England long before an attack was made with it. This allowed time for developing sufficient protection for the men.

It can be seen, therefore, that the present opportunity in chemistry is great, and the advancement already made shows that the American chemists are not behind those of other nations. The demand for men with a chemical training is enormous at the present time, not only for those who have had a training in research, but also those with simply a Bachelor's Degree. One concern wrote to me just the other day, stating that they had sixteen positions to be filled, and other similar instances are arising from time to time. I, personally, feel sure that the demand is not a temporary one but permanent, for the chemical industry in the United States is now on its feet. Whereas the salaries offered beginning chemists five years ago varied from $50 to $75 or $80 a month for a man who had had four years' undergraduate training, and $75 to $100 a month for men with considerable graduate training or even a Doctor's Degree, at the present time a concern would not consider offering less than $1,200 to $1,500 for a man who had had a college training in a good university, or less than $1,500 for a man with some graduate training, while to men with a Ph. D. the offers seldom fall below $2,000 and often are greater than that. This last June, one of our students who received his Doctor's Degree, a man who was not more than an average student, received a position at $2,300, and this fall was raised to $2,700, a salary which puts to shame the majority of the assistant professors' salaries in this and other universities.

It would be possible to consider almost indefinitely the various interesting phases of the chemical field, but I shall simply mention that large numbers of chemists are also needed in the oil industry, for water and food testing, for the development of new and more efficient antiseptics and drugs, for the study of new alloys for all kinds of engines, in fact for innumerable fields of the greatest importance.

Thus a few of the accomplishments of the American chemists and something of what they are attempting to accomplish have been put before you. A relatively large number of these have doubtless begun their chemistry in the high schools, and only when one is reminded of this is the importance of the work of the high school teacher realized. A student never loses his first impression of a subject, and it is possible thus to make or break a man for any field in the first few months of training. The new student must have his interest in the subject aroused, he must be made to feel the importance of it, and he must be able to see that chemistry is a connected field and not a mass of isolated facts.

PASCAL'S MOUNTAIN EXPERIMENT.

By Willard J. Fisher,
Worcester, Mass.

[Note: Strato of Lampsacus, director of the Lyceum at Athens, B. C. 287-269, called "the Physicist" from his interest and energy in promoting science as distinguished from *a priori* philosophy, seems to have studied the phenomena of air pressure then known, and to have explained what he found by the doctrine, "nature abhors a vacuum." Whether he owed this idea to Aristotle I do not know; but certainly little further progress was made for thirteen hundred years, when, it is said, the Arabian Alhazen seems to have had rather clear ideas about air pressure. In A. D. 1540 Cardan is said to have made attempts to determine the weight of air.

The Florentine pump-makers' observation, that water would not follow the piston above about thirty-two feet, when reported to Galileo led him to observe that nature apparently does not abhor a vacuum above thirty-two feet; and on reflection further, to suggest that the heights to which other liquids could be similarly raised might be inversely proportional to their specific gravities. Though he had previously determined experimentally that air has weight, by compression into a metal globe and weighing, he seems never distinctly to have connected the two sets of phenomena.

His pupil Torricelli was struck by the hint about specific gravities, and suggested mercury as a liquid. He never tried it, however, but passed on the suggestion to his pupil Viviani, who in 1643 did what we now call the *Torricellian experiment*, with the simple *barometer*—a name due to Robert Boyle. Torricelli was clear in his ideas as to the balancing of atmospheric and mercury pressures; "on the surface of the liquid in the basin there weighs a quantity of air fifty miles high." In connection with this experiment he said that it was not only for making a vacuum, "but also to have an instrument which can indicate the changes in the air, now heavier and more dense, now lighter and more subtle."

Descartes seems to have tried the same experiment with mercury twelve years before Torricelli, and in a letter to Father Mersenne to have explained it by air pressure; he complains that Pascal gave him no credit, though knowing about it. However that may be, in 1646 Pascal learned from Petit of Torricelli and Viviani's experiment, and was much struck with the possibility of making an empty space, a vacuum. At Rouen, with his informant Petit, he soon repeated and varied it with mercury and other liquids, using in one case red wine in a tube forty-six feet long. On December 13, 1647, Descartes again wrote Father Mersenne: "I have informed M. Pascal of an experiment to see whether quicksilver rises as high on a mountain top as at the bottom; I do not know whether he has done it." This is perhaps the origin of the famous experiment on the Puy de Dome, called Pascal's but carried out by Florin Perier, husband of Pascal's sister Gilberte. Pascal's proposition to Perier antedates this letter of Descartes to Mersenne by about a month.

Otto von Guericke, who in the midst of the savagery of the Thirty Years' War had carried out, in ignorance of the other researches of his time, experimental work which makes him one of the fundamental authorities, first heard of the Torricellian experiment with mercury and, no doubt, of Pascal's mountain experiment, in 1654, at Ratisbon, where he himself gained a European reputation by means of his air pump and Magdeburg hemispheres. He attempted to repeat the mountain experiment on the Brocken in 1658, but was disappointed by the clumsiness of the servant who carried the barometer and broke it part way there. The journey from Magdeburg was hard and uncomfortable, if not dangerous; already fifty-six years old, he did not try again.

The account which follows is translated from Hachette's edition of Pascal's works, Paris, 1872; it appeared originally in Paris, 1648. Descartes' relation to the discovery is taken from *La Grande Encyclopedie.*

The old French *toise* (fathom) consisted of 6 *pieds* (feet) of 12 *pouces* (inches) of 12 *lignes* (lines). "According to Nystrom's *Mechanics* 1 *pied du roi* = 12.79 inches," English measure.—WILLARD J. FISHER.

ACCOUNT OF THE GREAT EXPERIMENT ON THE EQUILIBRIUM OF FLUIDS PROPOSED BY M. B. PASCAL FOR THE COMPLETION OF THE TREATISE WHICH HE PROMISED IN HIS *Abstract on Vacuum*[1], AND MADE BY M. F. PERIER, ON ONE OF THE HIGHEST MOUNTAINS OF AUVERGNE, COMMONLY CALLED THE PUY DE DOME.

When I gave to the light of day my abstract under the title, *Experiences Nouvelles Touchant Le Vide, etc.*, in which I employed the maxim of the horror of a vacuum, since it had been universally received, and since I had no convincing proofs to the contrary, there were still certain difficulties which made me suspect the truth of this maxim, for whose clearing up I then contrived the experiment a description of which I am about to give, an experiment which enables me to give a perfect account of that which I am bound to believe about it. I have called it *the great experiment on the equilibrium of fluids*, since it is the most conclusive of all those which can be done on the subject, in that it shows the equilibrium of air and quicksilver, which are, the one the lightest, the other the heaviest, of all the fluids known in nature. But since it was not possible to do it in the city of Paris, and since there are very few places in France suitable for it, and since the city of Clermont in Auvergne is one of the most convenient, I begged M. Perier, counsellor in the Court of Aides of Auvergne, my brother-in-law, to take the trouble to try it. One may see what were my difficulties, and what the experiment is, by this letter which I then wrote him.

Copy of the Letter of M. B. Pascal, Jr., to M. Perier, of November 15, 1647.

Monsieur:

I would not interrupt the continuous labors in which your duties engage you, to discuss with you my meditations on physics, did I not know that they would serve to entertain you in your hours of leisure, and that in place of other things which might be disagreeable you might have a little diversion. Moreover, I feel less hesitation, as I know the pleasure that you get from that sort of discussion. This will be nothing more than a continuation of all those we have had concerning vacuum. You know the philosophers' opinions on that subject; they all have held as a maxim, that nature abhors a vacuum; and almost all, to go farther, have asserted that she cannot allow it, and that she would be destroyed rather than suffer it. Here opinions have been divided; some have been contented simply to say that she abhorred it; others have maintained that she could not suffer it. I have labored, in my *Abstract of a Treatise on Vacuum*, to destroy this latter opinion, and I believe that the experi-

[1]This complete treatise was never published.

ments which I have there reported suffice to make clear that nature can suffer, and in fact does suffer, a space as large as one may desire, empty of all the materials of which we know and which fall under our senses. My purpose now is, to examine the truth of the first, i. e., that nature abhors a vacuum; and to search for experiments to make clear if the effects which are attributed to the horror of a vacuum are really to be attributed to that, or whether they ought to be attributed to the weight and pressure of the air; since, to state frankly to you my idea, I have difficulty in believing that nature, which is neither animated nor conscious, is susceptible of horror, since passions presuppose a mind capable of experiencing them; and I incline rather to impute all these effects to the weight and pressure of the air, considering them only particular cases of a universal proposition about the equilibrium of fluids, which is to form the major part of the treatise I have promised. Not that I had not the same ideas at the time of producing my *Abstract;* nevertheless, lacking convincing experiments, I did not then dare (and I do not now dare) to give up the maxim of the horror of a vacuum; and I have likewise used this as a maxim in my *Abstract*, having there no other intention than to combat the opinion of those who assert that a vacuum is absolutely impossible, and that nature would suffer her own destruction rather than the least vacuous space. In fact, I hold that we are not permitted to depart even slightly from the maxims which we have received from antiquity, if we are not obliged to by indubitable and invincible proofs. But in that case I hold that it would be the extreme of weakness to make any scruples, and that finally we ought to have more veneration for evident truths than tenacity in received opinions. I cannot give you better evidence of the caution which I use rather than depart from the old maxims than by reminding you of the experiment which I performed in your presence in past days with two tubes, one inside of the other, which show plainly a vacuum within a vacuum. You saw that the quicksilver in the inner tube stayed suspended at the height which it takes in the ordinary experiment, when it was counterbalanced and pressed upon by the weight of the entire mass of air; but, on the contrary, it fell completely, without retaining either elevation or suspension, when, by reason of the vacuum which surrounded it, it was no longer pressed upon or counterbalanced by any air, this having been removed on all sides. You saw then that this height or suspension of the quicksilver increased or diminished as the pressure of the air increased or diminished, and finally that all the heights or suspensions of the quicksilver were always proportional to the pressure of the air.

Surely, after this experiment there would be room for persuasion that it is not a horror of a vacuum, as we deem it, which causes the suspension of the mercury in the ordinary experiment, but rather the weight and pressure of the air, which counterbalances the weight of the quicksilver. But since all the facts of this last experiment of the two tubes, so naturally explained by the pressure and weight of the air alone, can also be explained very plausibly by the horror of a vacuum, I clung to the old maxim; resolved, nevertheless, to search for a complete clearing up of the difficulty by a decisive experiment.

I have now imagined such a one, which shall be by itself sufficient to give us the light for which we search, if it can be carried out with precision. This is, to make the ordinary vacuum experiment several times the same day, in the same tube, with the same quicksilver, now at the base and again at the summit of a mountain, in height at least a hundred to six hundred toises, to test if the heights of the mercury suspended in the tube be equal or different in the two places. You see, no doubt, that the experiment is decisive of the question, and that, should it turn out that the mercury height is less at the top than at the base of the mountain (as I have many reasons for believing, though all who have thought on the subject are of contrary mind), it will necessarily follow that the weight and pressure of the air is the only cause of this suspension of the quicksilver, and not the horror of a vacuum; since it is certain that there is much more air which weighs upon the foot

of the mountain than on the summit, while one would not say that nature abhors a vacuum at the base of a mountain more than at the summit.

But as trouble usually comes joined to great deeds, I see enough of it in the execution of this plan, since for it must be chosen a very high mountain, near a city containing a person capable of bringing to the test all the needful precision; for, should the mountain be distant, it would be hard to carry there the vessels, the quicksilver, the tubes, and all other needful things, and to undertake the laborious journeys whenever it would be necessary, in order to have placid and convenient weather at the mountain top, which does not often happen there; and as it is also unusual to find outside of Paris people with the qualifications or places with the conditions, I have highly rated my happiness in having on this occasion found both one and the other, since our city of Clermont is at the base of the high mountain of the Puy de Dome, and since I hope of your goodness that you will grant me the kindness of being willing yourself to carry out this experiment; and with this assurance I have made hopeful of it all our Paris scientists, and among others Reverend Father Mersenne, who has already promised to cause his numerous and well-merited friends to share in the hope by letters about it to Italy, Poland, Sweden, Holland, etc. I will not touch upon the means of carrying it out, since I know well that you will omit no circumstance necessary to do it exactly.

I beg of you only that it may be as soon as you may find it possible, and that you will excuse this liberty, to which I am urged by my impatient anticipation of success, without which I cannot put final hand to my treatise promised the public, or satisfy the hope of so many expectant people, who also will be infinitely your debtors. Not that I would wish to diminish my gratitude by the number who will share it with me; as I desire, on the contrary, to share that which they will feel toward you; and on its account to remain, sir, your very humble and very obedient servant,

PASCAL.

M. Perier received this letter at Moulins, where he was on business which made him not his own master; so that, whatever desire he had to carry out the experiment promptly, he was nevertheless unable to do it sooner than last September.

You will see the reasons for the delay, the account of the experiment, and the exactness which he brought to it, from the following letter about it which he did me the honor to write.

Copy of the Letter of M. Perier to M. Pascal, Jr., of September 22, 1648.

Monsieur:

Finally I have done the experiment which you have so long desired. I would earlier have given you this satisfaction; but I have been hindered from it, as much on account of my duties in Bourbonnais, as by the reason that, since my return, the snows or the fogs have so covered the mountain of the Puy de Dome, where I was to carry it out, that, even at the season which is here the finest of the year, I have had trouble to find a day when it was possible to see the top of this mountain, which is usually within the clouds and sometimes above them, even though at the same time it be fair weather in the country: so that I have not been able to fit my convenience to the weather before the 19th of this month. But the pleasure with which I carried it out that day has completely consoled me for the small unpleasantness caused me by so many delays which I could not avoid.

Of this I give you here an ample and truthful account, in which you will see the precision and pains which I brought to it; beside which I

have thought proper to invite the presence of certain persons not less irreproachable than learned, in order that the sincerity of their testimony might leave no doubt of the certainty of the experiment.

Copy of the Account of the Experiment Made by M. Perier.

The weather of last Saturday, the 19th of this month, was very unsettled; however, as it seemed very fine towards five in the morning, and the top of the Puy de Dome showed itself uncovered, I resolved to go there to do the experiment. So I gave notice of it to certain persons of quality in this city of Clermont, who had asked me to inform them of the day I would go, some of whom are clerics and the rest lay: among the clerics were the Very Reverend Father Bannier, one of the Minimites[2] of this city, who has several times been Corrector (i. e., superior), and M. Mosnier, canon of the Cathedral Church of this city; and among the lay people, Mm. La Ville and Begon, counsellors in the Court of Aides, and M. La Porte, doctor of medicine practicing here; all persons not only very competent in their professions, but also highly cultivated, in whose company I was delighted to carry out this fine project. So we were all together that day towards eight in the morning, in the garden of the Minimite Fathers, which is nearly the lowest place in the city and where the experiment was begun in this way.

First, I poured into a vessel sixteen pounds of quicksilver, which I had rectified during the three days preceding; and having taken two glass tubes of equal size, and each about four feet long, hermetically closed at one end and open at the other, with each one of them I performed the common vacuum experiment in the same vessel; and having brought the two tubes in contact one with the other without withdrawing them from the vessel, it was found that when the quicksilver had come to rest in each it was at the same level, and that in each it was twenty-six pouces, three and one-half lignes above the surface in the vessel. I repeated this experiment in the same place, with the same two tubes, with the same quicksilver, and in the same vessel, two more times, and always it was found that the quicksilver in the two tubes was at the same level and the same height as the first time.

This done, I left behind one of the two tubes in its vessel in continuous experiment; I marked on the glass the height of the quicksilver, and leaving this tube in its place, I begged the Reverend Father Chastin, one of the religious of the house, a man equally pious and competent, who reasons very well in such matters, to take the pains to observe, from time to time during the whole day, if any change took place. And with the other tube and part of the same quicksilver, and with all these gentlemen, I was at the top of the Puy de Dome, elevated above the Minimites about five hundred toises, where, having made the same experiments in the same way as I had made them at the Minimites, it was found that it rested in this tube only at the height of twenty-three pouces, two lignes of quicksilver; instead of at the height of twenty-six pouces, three lignes and a half, as had been found at the Minimites in the same tube; and so, between the heights of quicksilver of the two experiments there was a difference of three pouces, one ligne and a half; which delighted us all with admiration and wonder, and amazed us so that, for our own satisfaction, we wished to repeat it. So I did it again five other times, very exactly, in various parts of the summit of the mountain, now under cover in the little chapel there, now in the open, now in shelter, now in the wind, now in fine weather, now during rain and fogs which occasionally happened, having each time most carefully cleared the tube of air; and there was always found in all these experiments the same height of quicksilver of twenty-three pouces, two lignes, which makes three pouces, one ligne and a half difference from the twenty-six pouces, three lignes and a half found at the Minimites; which satisfied us fully.

After, while descending the mountain, on the way I repeated the same experiment, always with the same tube, the same quicksilver, and the

[2]The Minim Friars of St. Francis de Paul.

same vessel, at the place called Lafon de l'Arbre, much above the Minimites, but much more below the summit of the mountain; and there I found that the height of the quicksilver at rest in the tube was twenty-five pouces. I repeated it the same time in the same place, and M. Mosnier, one of those named above, had the curiosity to do it himself; he also did it therefore in the same place, and he found always the same height of twenty-five pouces, which is less than that found at the Minimites by one pouce, three lignes and a half, and more than which we had just found at the top of the Puy de Dome by one pouce and ten lignes; which increased our satisfaction not a little, seeing the height of the quicksilver diminish according to the height of the place.

Finally, having returned to the Minimites, I found there the vessel which I had left in continuous experiment, at the same height as I had left it, twenty-six pouces, three lignes and a half; in which height Reverend Father Chastin, who had remained there for observation, informed us no change had occurred during the whole day, although the weather had been very unsettled, now serene, now rainy, now full of clouds, now windy.

I repeated the experiment with the tube which I had taken to the Puy de Dome, and in the vessel where was the tube in continuous experiment; I found that the quicksilver was at the same level in the two tubes, and at the same height of twenty-six pouces, three lignes and a half, as it had been found in the morning in the same tube, and as it had remained during the whole day in the tube in continuous experiment.

I repeated it again for the last time, not only in the same tube which I had used on the Puy de Dome, but also with the same quicksilver and in the same vessel which I had carried there, and I always found the quicksilver at the same height of twenty-six pouces, three lignes and a half, which had been found in the morning; which finished confirming us in the certainty of the experiment.

The next day the Reverend Father de la Mare, priest of the Oratory and theological lecturer of the Cathedral Church, who had been present at what had occurred the morning of the preceding day in the Minimite garden, and to whom I had recounted what had happened on the Puy de Dome, proposed to me to try the same experiment at the foot and at the top of the higher tower of Notre Dame de Clermont, to test if there might occur any difference. To satisfy the curiosity of a man of so great merit, who has given all France proofs of his capacity, I did the same day the common experiment of vacuum, in a certain house which is at the highest place in the city, elevated above the garden of the Minimites six or seven toises, and at the level of the foot of the tower; there we found the quicksilver at a height of about twenty-six pouces, three lignes, less than that found at the Minimites by about half a ligne.

Then I did it at the top of the same tower, elevated above its foot about twenty-six or twenty-seven toises; there I found the quicksilver at a height of about twenty-six pouces, one ligne, which is less than that found at the foot of the tower by about two lignes, and than that found at the Minimites by about two lignes and a half.

(Here follows a numerical resume, which I omit.—W. J. F.)

Behold, in truth, all that happened in this experiment, the account of which all the gentlemen who assisted with it will sign when you desire.

Further, I have to tell you that the quicksilver heights were taken very exactly; but of the places where the experiments were made, those were probably less so.

Should I have enough leisure and convenience, I will have them measured with more precision; and I will also have marked down in hundreds of toises the places on the mountain at each of which I shall have done the experiment, and the heights found for the quicksilver at each of these stations, in order to give you exactly the difference produced by the first hundred toises, that by the second hundred toises, and so with the others; which might serve for arranging a table of it, by the extension of which those who might wish to give themselves the trouble could

perhaps arrive at a perfect knowledge of the exact size of the diameter of the whole sphere of the air.

I do not despair of sending you some day these differences for hundreds of toises, as much for our satisfaction as for the use the public could get out of it.

If you find any obscurity in this account, I will be able in a few days to enlighten you by word of mouth, being at the point of making a little trip to Paris, where I will assure you that I am, sir, your very humble and very affectionate servant, PERIER.

This account having cleared up all my difficulties, I will not conceal that I received from it much satisfaction; and having seen by it that the difference of twenty toises in elevation makes a difference of two lignes in the height of the quicksilver, and that six to seven toises make a difference of about half a ligne, which was easy to test in this city, I did the ordinary experiment of the vacuum at the top and at the bottom of the tower of Saint Jacques de la Boucherie, twenty-four to twenty-five toises high; I found more than two lignes difference in the height of the quicksilver; and then I did it in a certain house, ninety steps high, where I found very sensibly a difference of half a ligne; which agrees perfectly with the contents of M. Periér's account.

All those who are curious can try it themselves, whenever they please.

CONSEQUENCES.

From this experiment there may be drawn numerous consequences, as—

The means of determining whether two places are at the same level, i. e., equally distant from the center of the earth, or which of the two is the more elevated, if the two are at a distance apart, even though they be antipodes; which would be otherwise impossible.

The small certainty found in the thermometer[3] for marking the degrees of heat, contrary to common opinion; for its water often rises when the heat increases, and on the contrary often falls when the heat diminishes, even though the thermometer has stayed in the same place.

The inequality of the pressure of the air, which, with the same degree of heat, is always found much more pressed in lower places.

All these consequences will be deduced in full in the *Treatise on Vacuum*, and many others as useful as curious.

[3] An air thermometer on the model of Galileo's?

TO THE READER.

My dear reader, the universal consent of peoples and of the throng of philosophers agrees in the establishment of this principle, that nature would rather suffer her own destruction than the least vacuous space. Certain intellects more elevated have adopted one more moderate; while they have still believed that nature has a horror of a vacuum, they have nevertheless judged that this repugnance has limits, and that it can be overcome by a certain amount of violence; but there has never been anyone to advance this third—that nature has no repugnance whatever for a vacuum, that she makes no effort whatever to avoid it, and that she allows it without trouble and without resistance.

The experiments which I have given you in my *Abstract* have, in my judgment, destroyed the first of these principles; and I do not see how the second can resist this which I am now giving you; so that I no longer make any trouble of accepting the third, that nature has no repugnance whatever for a vacuum, that she makes no effort whatever to avoid it, that all the effects which have been attributed to this horror proceed from the weight and pressure of the air, which is their sole true cause, and that, for lack of knowledge, this imaginary horror of a vacuum has been expressly invented to account for them. Not in this case alone, when the weakness of men has been unable to find true causes, their subtlety has substituted for them imaginary ones, expressed by specious names, filling the ears and not the mind; as when they say that the sympathy and antipathy of natural bodies are the efficient and unique causes of various effects—as if inanimate bodies were capable of sympathy and antipathy; similarly with *antiperistasis*, and numerous other chimerical causes, which bring only an empty satisfaction to men's desire for knowing hidden truths, and which, instead of discovering such, serve only to cover the ignorance of their inventors and to nourish that of their followers.

It is not wholly without regret that I depart from opinions so generally received; I do it only as yielding to the power of truth which constrains me. I have opposed these new ideas as long as I have had any excuse for following the old; the maxims which I have followed in my *Abstract* testify of this sufficiently. But at last the evidence of experiments has forced me to leave opinions in which respect for antiquity had kept me. Moreover, I have left them only little by little and have

departed from them by degrees; for, from the first of these principles, that nature has an invincible horror of a vacuum, I passed to the second, that she has a horror for it, but one not invincible; and from that I have finally arrived at belief in the third, that nature has no horror whatever for a vacuum.

This is where this last experiment on the equilibrium of fluids has brought me; which I would not have thought to give you complete, without showing you what motives incited me to the search; for that reason I give you my letter of November 16 last, addressed to M. Perier, who took the trouble to do it with all the exactness and precision that can be desired, and to whom all the scientists who have so long desired it will be under great obligation.

And since, for a special advantage, this universal desire has made it famous before its appearance, I am sure that it will not become less renowned after its completion, and that it will give as much satisfaction as the expectation of it has caused impatience.

It was not proper to let the people who had desired it languish for it any longer; and for that reason I could not refrain from giving it in advance, contrary to my plan not to except in the complete treatise (which I have promised you in my *Abstract*) in which I will deduce the consequences that I have drawn from it; which I have deferred doing until this last experiment, as it is needed to make my demonstrations complete. But since that cannot appear so soon, I have been unwilling to keep this any longer, as much to deserve from you more gratitude for my promptness as to avoid the reproach of wrongdoing, which I might expect you to bring against me for delaying too long.

Price of Preprints of the "Status of Mathematics in Secondary Schools."

Preprints of this article, published in the January, February, March and April issues, may be had for 10 cents from Mr. M. J. Newell, High School, Evanston, Ill., or from Mr. Alfred Davis, Francis W. Parker School, 330 Webster Ave., Chicago, Ill.

SCIENCE TEACHING IN SOUTH DAKOTA.

By Hilton Ira Jones, Ph. D.,
Dakota Wesleyan University, Mitchell, South Dakota.

Educational surveys are not for the purpose of "getting some one" as certain people seemed to fear when the proposition of appropriating state funds was up before the legislature. But as Superintendent McClinton pointed out in his Presidential address, the fact that any authority classes us as twenty-sixth in schools should deeply concern every educator in the state. And surely before we can intelligently set about to remedy our defects, we must have a clear understanding of just what these defects are. Hence the legislature is to be congratulated on having made provision for a thoroughgoing survey of the educational conditions in South Dakota.

In my Presidential address at Watertown before the South Dakota Academy of Science, I called attention to the unfortunate conditions of science teaching in South Dakota, the deplorable consequences resulting, and urged the Academy to make a study of the conditions under which secondary science work is attempted in our state. In accordance with this recommendation I have undertaken to gather such information as I could from the science teachers and others in the many towns of the state which I have visited in the last few years. In addition to the data which I have thus collected from many sources, I sent out a questionnaire to all the high schools in South Dakota. The questions asked were:

1. What science courses are taught in your school?
2. How many teachers give science courses?
3. What is your average science teacher's salary?
4. How many classes per day do your science teachers average?
5. What is the length of your class periods?
6. Do your science classes have single or double laboratory periods?
7. How many students are there in your high school?
8. How many students are taking physical geography? General science? Botany? Zoology? Biology? Chemistry? Physics? Agriculture?
9. What is the (estimated) value of the laboratory equipment used for each science you teach?
10. What is the average annual expenditure for science equipment and supplies?
11. Who determines how much shall be expended?
12. Who determines what shall be purchased?
13. Have your science teachers had special training for this work?
14. How many laboratory sciences have you?
15. Are your science courses gaining or decreasing in popularity?
16. What apparatus and supply company or companies do you find most satisfactory?

That South Dakota educators are ready for an educationa survey and are willing to cooperate and make it successful is

clearly shown by the unusually large percentage of carefully worked-out answers which I received. Practically all the four-year accredited high schools in the state replied. Nearly all the failures to respond were in the case of small unaccredited high schools, many of which felt, as one principal expressed it, that inasmuch as they had no laboratory or scientific equipment, their data would not be very enlightening or valuable. Consequently, the showing made by the replies to the questionnaire is a little better than the facts.

From the one hundred and twenty-four replies received, I find that the number of schools teaching the several sciences arrange themselves as follows:

Geology	1	Physical Geography	78
Physics	71	General Science	47
Physiology	5	Zoology	10
Chemistry	21	Botany	38
Agriculture	37	Biology	6

It thus appears that the weight of precedent is opposed to the teaching of geology, physiology, biology, and zoology in the high schools of the state, the prejudice against them being in the order named. I find zoology is taught in but two of the larger high schools, biology and physiology in but one, and geology in no large high school. It would seem that the high schools teaching these sciences would do well to inquire whether the special reasons which impel them to teach these sciences are sufficient to justify their continuance in the face of overwhelming public opinion. While there are twenty-one high schools teaching chemistry, judging by the amount of money invested in equipment, there are many more teaching it than should attempt to do so.

The numbers enrolled in the various sciences is of some interest:

	Total Enrollment.	Size of Average Class.
Geology	4	4
Physiology	52	10.4
Zoology	215	21.5
Physics	903	11.3
Chemistry	394	18.8
Agriculture	630	17.02
Botany	674	17.7
Physical geography	1,314	17.0
General science	948	20.1
Biology	105	17.5
	5,239	Average 15.53

The figures showing the salary of the high school science teacher have very little meaning, because in a very large number of cases the science teacher is either principal or superin-

tendent, and the salary he receives is partly for his science teaching and partly for his work in administration. The average salary appears to be $968.76. The high schools have on the average 1.65 science teachers. The average number of classes is 4.5, but inasmuch as only some dozen high schools possess real science teachers, that is, teachers who are specialists in science teaching, and teach little or nothing else, the figures have no great significance. The class periods are all the way from thirty to sixty minutes in length, with the forty-five-minute period very much predominating. I find that fifty-three high schools report double laboratory periods in all their sciences; twenty high schools have double laboratory periods for some of their sciences, and single for others. Twenty-one high schools have only single periods. These are among the smaller high schools which also have on the average the shorter periods. I have throughout used the word "smaller" high school to indicate an enrollment of less than seventy, as our South Dakota high schools average 71.2 enrollment.[1]

The average valuation placed upon the entire science equipment by the high schools reporting is $637.22, and if every high school had an equipment of this value before it attempted to teach science subjects, the case would not be bad. But when we observe the number of high schools teaching from one to five sciences with an equipment valued at less than $100.00, we see how desperate the need of equipment is. I note for example a high school teaching five sciences with a total equipment valuation of $50.00 and an annual expenditure of $5.00. Such a state of affairs seems incredible to me. I have taught science for ten years and have never spent less than $500.00 a year, and half of this time was spent in high schools. Our annual expenditure at Dakota Wesleyan for the five laboratory courses under my direction is from $1,500.00 to $1,900.00. And how any human being can be expected to teach science in a respectable way with an equipment such as a very large number of South Dakota high schools possess, I confess is beyond me to understand. It simply cannot be done, it is not done, that's all. The average annual appropriation in South Dakota high schools for all the sciences is but $79.42, and remember the average high school has 3.1 science subjects. That gives $26.47 as the average annual cost for supplies and equipment to teach science a year to the average science class of 15.53 pupils or .95 of a cent per pupil recitation. In view of these figures I would

[1]The reader should remember that South Dakota has a population of less than seven to the square mile and not two cities of ten thousand people.

reply to the question which I am frequently asked, "What is the matter with the science work in South Dakota?" the trouble is that on the average the school boards are trying to get something for nothing, which can no more be done in science teaching than anywhere else. In the Central High School, Muskogee, Okla., we estimated the science courses to average three cents per pupil recitation. The Mitchell High School figures as reported give 2.2 cents per pupil recitation. In general the cost per pupil recitation increases as the size of the school decreases; this, of course, is because the same demonstration apparatus required for a small class will do equally well for a larger one. And yet it is the smaller high schools of South Dakota with the average total enrollment of less than seventy which are responsible for the abnormal figures already given.

The person best qualified to judge as to the needs of a science department is, of course, the instructor, and yet in but seven high schools in the state (and probably here the instructor is an administrative official), does the instructor determine how much should be spent for supplies and equipment. In eight schools the superintendent very generously calls in the instructor for consultation. In three schools the board and instructor determine the amount that should be expended. In seventeen schools the reports show that the superintendent alone determines the expenditure. In twenty-three cases the board and superintendent determine the appropriation, and in thirty-two school systems the board alone determines it. The order of knowledge of the needs is instructor, superintendent, board; but the order of selection is just the reverse. The men who most generally choose are the men who know the least about it. In six towns the board even presumes to say what shall be bought as well as how much shall be expended.

It seems to me the unescapable conclusion which we must come to in answer to the question, "Who is to blame for the poor science work in the high schools of South Dakota?" is the school board. A rather extensive acquaintance with the calibre of the school boards of the average small town strengthens me in this conclusion.

The answers received to the question, "Have your science teachers had special training for this work?" and my acquaintance with the science teachers of the state convince me that there is little common understanding as to what is meant by special training. Special training to me means graduate study in the

subject, but I note, for example, that one instructor who never had a science course in his high school work and never a course in his college work that he would ever teach in a high school, and who got the only physics training he ever received in a six weeks' summer normal after graduation, reports that he has had special training in science teaching. How large a percentage of the high school science teachers in our state have had special graduate training in the sciences they teach, I am unable to say, but I feel certain the percentage is very small.

The high schools average 3.1 science subjects taught, but only 2.66 sciences which they class as laboratory sciences. There is a vast difference between studying science, the aim of which study is to produce scientists, and studying about science for its "cultural value," after the manner of the bean-eaters of the effete East.

Fifteen high schools report that their science courses are in a static condition, while sixty-six report that they are gaining in popularity, and none report that they are waning in popularity.

Yes, you will say, these are the conditions, but what remedy do you suggest? There are two remedies: First, let the state pay a bonus to the high schools of the state whose work is up to standard as is done in Minnesota. Second, let the state refuse to recognize or accept the credits of any high school which is not up to standard.

SOMETHING NEW.

The old adage that there is nothing new under the sun does not apply in science teaching. New ways of performing experiments, and novel pieces of lecture demonstration apparatus, are continually being announced.

For years the writer has used the Von Nardroff color mixer in illustrating color, primary and complementary colors, etc. This color mixer, while undoubtedly the best of its kind, does not demonstrate color blindness. Physics teachers for years have felt the need of proper apparatus that could illustrate this defect of the human eye.

But now C. M. Westcott of Los Angeles has just developed a very satisfactory device for testing pupils' color perception. It is in the form of lantern slides with forty shades of color ingeniously arranged and numbered. By its use one pupil or an entire class can be singly or collectively tested at the same time, and the exact shade and amount of color defect be ascertained in a few minutes. Every general science teacher and physics teacher should get a set for use in his own classes. It will prove to be one of the most interesting, spectacular, practical, and profitable pieces of apparatus in the laboratory.

See Mr. Westcott's advertisement elsewhere in this issue. C. M. T.

PROBLEM DEPARTMENT.

Conducted by J. O. Hassler.

Crane Technical High School and Junior College, Chicago.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics. Besides those that are interesting per se, *some are practical, some are useful to teachers in class work, and there are occasionally some whose solutions introduce modern mathematical theories and, we hope, encourage further investigation in these directions. All readers are invited to propose problems and solve problems here proposed. Problems and solutions will be credited to their authors. In selecting solutions for publication, we consider* accuracy, completeness, *and* brevity *as essential. Address all communications to J. O. Hassler, 2301 W. 110th Place, Chicago.*

Algebra.

531. *Proposed by G. L. Wagar, Mount Hermon, Mass.*

Given that the sum of the following four factors is -1, find (1) the product of the first pair; (2) the product of the second pair; (3) the product of the sum of the first pair by the sum of the second pair.

$$x+x^4+x^{13}+x^{16}$$
$$x^2+x^8+x^9+x^{15}$$
$$x^3+x^5+x^{12}+x^{14}$$
$$x^6+x^7+x^{10}+x^{11}$$

Taken from *Teachers Handbook of Algebra*, by McLellan.

Solution by L. E. Mensenkamp, Freeport, Ill.

(1) Multiplication of the first pair of factors gives the sum of 16 terms of the type x^k, where $k = 3, 6, 15, 18, 9, 12, 21, 24, 10, 13, 22, 25, 16, 19, 28, 31$. The given condition that the sum of the four factors is equal to -1 may be expressed by the equation

$$x^{16}+x^{15}+x^{14}+\cdots+x+1 = 0, \qquad \text{(a)}$$

or $\dfrac{x^{17}-1}{x-1} = 0$. From the last equation it follows that

$$x^{17} = 1. \text{ Then, } x^{18} = x,\ x^{19} = x^2,\ \cdots,\ x^{n+17} = x^n. \qquad \text{(b)}$$

Using these equations, all terms x^k may be reduced to equivalent terms with exponents equal to or less than 16. The product of the first pair of factors then reduces to $x^{16}+x^{15}+x^{14}+\cdots+x$. By equation (a), this equals -1.

(2) Similarly, the product of the second pair may be shown to equal -1.

(3) Finally, the product of the sum of the first pair by the sum of the second pair is the sum of 64 terms of the type x^k. By equations (b), these may be reduced to $4(x^{16}+x^{15}+x^{14}+\cdots+x) = -4$.

A solution similar to the above was received from R. M. Mathews, Riverside, Cal.

Geometry.

532. *Proposed by R. M. Mathews, Riverside, Cal. Lemma for* 513.

A variable circle with center on the line l and passing through a fixed point P, cuts a fixed circle C in A and B. Prove that the common chord AB and the perpendicular to l through P intersect in a fixed point R.

Solution by the proposer.

RP $\perp l$ at D. CE $\perp l$ at E. r = radius of circle C. Draw CR, CD.

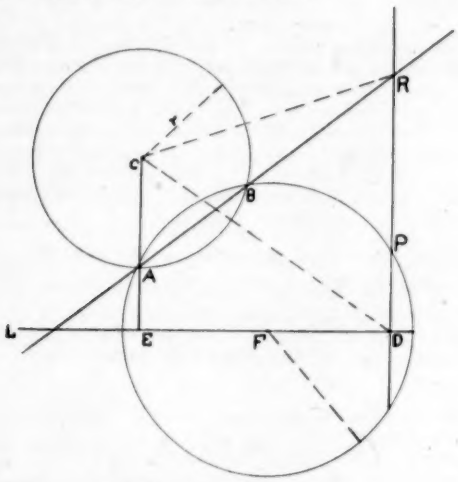
Prove RD const.

Proj. of CD on RP = CE.

$\overline{RC}^2 = \overline{CD}^2+\overline{RD}^2-2\overline{RD}\cdot\overline{CE}.$

$\overline{RC}^2-\overline{RD}^2 = \overline{CD}^2-2\overline{RD}\cdot\overline{CE}.$

But $\overline{RC}^2-r^2 = \overline{RA}\cdot\overline{RB} = \overline{RD}^2-\overline{PD}^2.$



$\therefore\quad \overline{RC}^2-\overline{RD}^2 = r^2-\overline{PD}^2$

$\therefore\quad 2\overline{RD}\cdot\overline{CE} = \overline{CD}^2+\overline{PD}^2-r^2$

$$\overline{RD} = \frac{\overline{CD}^2+\overline{PD}^2-r^2}{\overline{2CE}} = \text{a const.}$$

Nelson L. Roray, Metuchen, N. J., remarks that "This proposition enables us to construct a circle tangent to a given circle and passing through two fixed points."—*Editor.*

533. *Proposed by Daniel Kreth, Wellman, Iowa.*

In the triangle ABC perpendiculars to AC and BC, respectively, are drawn from C intersecting AB in E and D. $\angle ACE = \angle BCD = 90°$; $CD = l$, $CE = m$, $AD = n$, and $BE = p$. Find the remaining parts of the triangle.

I. *Solution by L. E. A. Ling, La Grange, Ill.*

Draw the altitude CK on AB.

Put $DK = x$. $EK = y$.

From rt. $\triangle$s ACE, CDB,

$$(n+x)y = (p+y)x. \qquad (1)$$

From $\triangle$ CDE,

$$y^2-x^2 = m^2-l^2 \qquad (2)$$

From (1) and (2), $y = p\sqrt{\dfrac{m^2-l^2}{p^2-n^2}}$,

and $x = n\sqrt{\dfrac{m^2-l^2}{p^2-n^2}}$.

Now $c = n+p+x+y$

$$= n+p+(n+p)\sqrt{\frac{m^2-l^2}{p^2-n^2}}.$$

If angle BCA is obtuse the formula is

$$c = -n-p+(n+p)\sqrt{\frac{m^2-l^2}{p^2-n^2}}$$

—Ed.

$$a^2 = m^2+p^2+2py$$
$$= m^2+p^2+2p^2\sqrt{\frac{m^2-l^2}{p^2-n^2}}.$$
$$\therefore a = \sqrt{m^2+p^2+2p^2\sqrt{\frac{m^2-l^2}{p^2-n^2}}}$$

Similarly,

$$b = \sqrt{l^2+n^2+2n^2\sqrt{\frac{m^2-l^2}{p^2-n^2}}}$$

. *For obtuse angle signs of $2p^2$ and $2n^2$ are negative in formulae for a and b.—Ed.*

A solution was also received from Isidore Ginsburg, New York.

534. *Proposed by J. A. van Groos, Portland, Oregon.*

Of the three inscribed squares on the three sides of a triangle, the largest square is on the smallest side.

I. *Solution, L. E. A. Ling, La Grange, Ill.*

Let $a>b>c$ be the sides of the $\triangle$, and h, h', h'', be the altitudes of the $\triangle$ and x, y, z, respectively, the sides of the inscribed squares.

To prove $z^2>y^2>x^2$.

Proof. $a : x = h : h-x.$

Then $$x = \frac{ah}{a+h}.$$

Similarly, $$y = \frac{bh'}{b+h'}.$$

$$\therefore \frac{x}{y} = \frac{b+h'}{a+h'}. \quad (ah = bh' = 2\triangle s.)$$

Also $$h' = \frac{ah}{b}.$$

Whence, $$\frac{x}{y} = \frac{b^2+ah}{ab+bh}$$

Since $a>b$, put $a = b+d$

Then $$\frac{x}{y} = \frac{b^2+bh+hd}{b^2+bh+bd}$$

Now $bd>hd (c>h, bd>cd)$

$$\therefore y > x.$$
$$\therefore y^2 > x^2.$$

Similarly, $z^2 > y^2$.

$z^2>y^2>x^2$.

II. *Solution by Nelson L. Roray, Metuchen, N. J.*

Let c, h_c and x_c denote the side of a triangle, the altitude upon the side and the side of the square inscribed upon the side respectively.

Then it is easily proved that

$$x_c = \frac{ch_c}{h_c+c}$$

$$x_c : x_b = \frac{ch_c}{h_c+c} : \frac{bh_b}{h_b+b}$$

$$= \frac{h_b + b}{h_c + c}$$

$$= \frac{A\sin C + A\sin B}{\dfrac{\sin(B+C)}{A\sin B + A\sin C}}$$

$$= \frac{\sin C\sin(B+C) + \sin B}{\sin B\sin(B+C) + \sin C}$$

But $\sin C\sin(B+C) + \sin B - \sin B\sin(B+C) - \sin C$ is equal to $(\sin B - \sin C)(1 - \sin(B+C))$, a positive number, if $B > C$.

$\therefore x_c > x_b$ if $B > C$ or $c < b$.

Note: If $B + C = 90$, then $(\sin B - \sin C)(1 - \sin(B+C)) = 0$ and $x_c = x_b$. Hence the theorem is not universally true.

This exception was also noted by the proposer in a solution to the problem. A solution was also received from Charles H. Bartlett, Champaign, Ill. —Editor.

535. *Proposed by Frank Edwin Wood, Albuquerque, N. M.*

Let PA and PB be two chords of a circle, let PC be the perpendicular to AB, then $PA \cdot PB = PC \cdot 2R$, where R is the radius.

I. *Note by L. E. Mensenkamp, Freeport, Illinois.*

This is a form of the well known theorem in geometry which is usually stated as follows: *The rectangle formed by any two sides of a triangle is equivalent to the rectangle formed by the altitude upon the third side and the diameter of the circumscribing circle.* For a proof of the theorem, see Milne's *Plane and Solid Geometry*, p. 194.

Reference to the proof of this theorem in standard texts was also made by L. E. A. Ling, Murray J. Leventhal and Isidore Ginsburg. It is treated as a corollary of the theorem mentioned above in a solution by Emlyn Roberts, a student in Dunmore (Penn.) High School. The solution below differs from the standard proofs.—Ed.

II. *Solution by R. M. Mathews, Riverside, Cal.*

PAB is a triangle inscribed in a circle, so

$$\text{Area } \triangle PAB = \frac{PA \cdot PB \cdot AB}{4R}.$$

Also,

$$\text{Area } \triangle PAB = \tfrac{1}{2}PC \cdot AB$$

$$\therefore \frac{PA \cdot PB \cdot AB}{4R} = \tfrac{1}{2}PC \cdot AB$$

whence $PA \cdot PB = PC \cdot 2R$.

Solutions were also received from Charles H. Bartlett, Frank Brink, Felix S. Hales, David B. Munroe, Ella M. Richards, Nelson L. Roray and the Proposer.—Editor.

News Notes.

The editor is sure that many will be interested in the following extracts from a letter recently received from Norman Anning, dated October 27, 1917, mailed "somewhere in France."

All goes well. Am 'carrying on' with the kind of work I came over to

do. . . . About a year ago you had a problem expressing $(x^2+y^2+z^2)^2$ as the sum of three squares. Find enclosed a general solution. Have no opportunity of studying mathematics or doing problems other than those in the geometry of location and the arithmetic of equating 25 francs to the H. C. of L.

Sequel to Problem 502.

By Norman Anning.

To express

$(x^2+y^2+z^2)^n$ (x, y, z, n, positive integers)

as the sum of three squares.

Let $y^2+z^2 = s^2$ and let

$(x+is)^n = p+iq$, $(i^2+1 = 0)$.

Then

$(x-is)^n = p-iq$.

And, multiplying,

$(x^2+s^2)^n = p^2+q^2$,

$$(x^2+y^2+z^2)^n = p^2+q^2\left(\frac{y^2+z^2}{s^2}\right),$$

$$= p^2+\left(\frac{qy}{s}\right)^2+\left(\frac{qz}{s}\right)^2.$$

Note that q is divisible by s and, consequently, $\left(\frac{qy}{s}\right)$ and $\left(\frac{qz}{s}\right)$ are integers. We have thus a way of expressing any positive integral power of the sum of three squares as the sum of three squares.

Example: $n = 3$.

$(x+is)^3 = (x^3-3xs^2)+i(3x^2s-s^3)$.

Then

$$(x^2+y^2+z^2)^3 = x^2(x^2-3y^2-3z^2)^2, \\ +y^2(3x^2-y^2-z^2)^2, \\ +z^2(3x^2-y^2-z^2)^2.$$

Putting $x = 1, y = 2, z = 6$ we have

$41 = 1^2+2^2+6^2$,

$41^3 = 74^2+119^2+222^2$.

The same method can be used for any number of squares other than three.

PROBLEMS FOR SOLUTION.

546. *Proposed by W. W. Gorsline, Crane Technical High School and Junior College, Chicago.*

The following six groups of numbers, A, B, C, D, E, F, comprise a well known game or "puzzle." Any number less than 64 is selected and the groups in which it occurs are denoted, e. g., 37: in A, C and F. By adding the first numbers in the respective groups the number is determined, as $1+4+32 = 37$. Find the secret of arrangement of numbers and possibly derive a formula of arrangement for n groups.

A								B							
1	3	5	7	9	11	13	15	2	3	6	7	10	11	14	15
17	19	21	23	25	27	29	31	18	19	22	23	26	27	30	31
33	35	37	39	41	43	45	47	34	35	38	39	42	43	46	47
49	51	53	55	57	59	61	63	50	51	54	55	58	59	62	63

C

4	5	6	7	12	13	14	15
20	21	22	23	28	29	30	31
36	37	38	39	44	45	46	47
52	53	54	55	60	61	62	63

D

8	9	10	11	12	13	14	15
24	25	26	27	28	29	30	31
40	41	42	43	44	45	46	47
56	57	58	59	60	61	62	63

E

16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63

F

32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63

547. *Proposed by Norman Anning, France.*

The cap and sill of a high trestle bent are respectively 150 and 400 inches long. Find the lengths of three intermediate caps which are so spaced that the diagonal braces are parallel from top to bottom.

Geometry.

548. *Proposed by Nelson L. Roray, Metuchen, N. J.*

Three points, A, B, and C, start from S on the circumference of a circle to move around the circumference at uniform rates, a, b, and c, respectively. If length of the circumference is P and $c>b>a$ find the condition that the first time they are together again shall be at S; also the time that is required for them to meet again at S.

549. *Proposed by Murray J. Leventhal, New York City.*

Given an equilateral triangle, ABC, and point P, so that PA = PB +PC. Show that the locus of P is a circle. [From a New York City examination for teachers.]

550. *Proposed by Daniel Kreth, Wellman, Ia.*

Given the altitude and radii of the circumscribed and inscribed circles of a plane scalene triangle, to construct it and determine its sides.

SCIENCE QUESTIONS.

Conducted by FRANKLIN T. JONES,
University School, Cleveland, Ohio.

Readers are invited to propose questions for solution—scientific or pedagogical—and to answer questions proposed by others or by themselves. Kindly address all communications to Franklin T. Jones, University School, Cleveland, Ohio.

Please send examination papers on any subject or from any source to the Editor of this department. *He will reciprocate by sending you such collections of questions as may interest you and be at his disposal.*

285. *Proposed by M. W. Arps, U. S. S. Ohio, c-o Postmaster, New York.*

"A" claims that if two balls of equal diameter, but of different material, one being lead and the other wood, be dropped in air from a height of one mile, that they would both reach the ground at the same time.

"B" claims that the lead ball would reach the ground first.

Which is correct?

286. *Proposed by John C. Packard, Brookline, Mass.*

Why does the image in a plane mirror, held parallel to the object, appear reversed but not inverted?

287. *Proposed by O. L. Brauer, Selma, Cal.*

To what extent is crystal formation dependent on water of crystallization?

288. *Proposed by Clifford Laisy, West Technical H. S., Cleveland, Ohio, through W. A. Tippie.*

Reconcile these two statements of electrical phenomena: (*a*) electric charges are always located on the surface of conductors; (*b*) electrical resistance of a uniform conductor is inversely proportional to the square of the diameter.

Please answer questions numbered 289 and 290 in the following lists: Submitted by Walter N. Lacy, Anglo-Chinese College, Foochow, China.

PHYSICS, 1ST TERM, JUNE, 1917.

Answer only 8 questions; but at least one question from each group must be answered.

GROUP I.

1. How can the specific gravity of a liquid be found? Give reasons for everything done in this method.
2. Make a diagram to show how you would arrange 4 pulleys to lift a heavy weight, and explain how you could find the efficiency of the system.
3. Why do people fan themselves in summer? Explain fully. Tell how you can prove the correctness of your answer.

GROUP II.

4. A man rows a boat across a stream three-fourths of a mile wide, at the rate of 3 miles per hour. The current carries him down stream at the rate of 2 miles per hour. How long does it take him to cross the stream?
5. Depths of the sea are measured by lowering some kind of a pressure gauge into the sea. When this is done until the gauge shows a pressure of 1.3 kg. per sq. cm., what is the depth? (The specific gravity of sea water may be considered as 1.026.)

289. If a burner can heat 2 kg. of water from 10° to 80° C. in 10 minutes, how much water can it boil away into steam in one hour?

GROUP III.

7. Tell what you can about Newton, and what he did for Physics.
8. When you cut cardboard with scissors, why do you open them wide and cut near the point where the two blades are pivoted together?
9. Which is the more useful formula for measuring the efficiency of a motor or engine, $\frac{\text{work out}}{\text{work in}}$ or $\frac{\text{power out}}{\text{power in}}$? Give reasons for your answer.
10. What does a thermometer measure? How? Describe the Centigrade thermometer.
11. Give a brief account of the history of the steam engine.

Submitted by Dr. Lyman C. Newell, Boston University, Boston, Mass.

CHEMISTRY, SEPTEMBER, 1917.

Time: one hour, thirty minutes.

GROUP I. (*Answer two questions in this group.*)

1. State the special property on which the use of each of the following is based: Magnesium, ammonium sulphate, calcium carbide, mercury, thermit.
2. Describe the process of manufacturing each of the following: Sodium hydroxide, lime, nitric acid.
3. (a) Describe the contact process of making sulphuric acid. (b) How is copper purified? (c) What is the difference between gunpowder and smokeless powder?

GROUP II. (*Solve one problem in this group.*)

1. Sixty grams of mercuric oxide are decomposed; what volume of oxygen at 91° C. and 380 mm. is liberated?

2. How many gm. of gold in a 14 carat ring which weighs 14 grams?

290. If 2 gm. of potassium chloride yield 3.84 gm. of silver chloride, what is the atomic weight of potassium?

(Note.—At. wts.: Hg = 200.5, Ag = 108, Cl = 35.5.)

GROUP III. (*Answer two questions in this group.*)

1. Describe an experiment to illustrate neutralization. Sketch the apparatus. Write the equation in the ionic form.

2. Describe the method by which you prepared one of the following: (a) CO_2; (b) sulphurous acid; (c) nitrogen. Sketch the apparatus.

3. Describe an experiment to illustrate one of the following: (a) Supersaturation; (b) electrolytic dissociation; (c) hydrolysis.

4. Describe a method to find one of the following: (a) The per cent of solid in a given solution; (b) the equivalent weight of aluminium.

5. What is the test for (a) $Cl-$, (b) a sulphate, (c) ammonia?

GROUP IV. (*Answer two questions in this group.*)

1. (a) Explain efflorescence. (b) State and illustrate Avogadro's hypothesis. (c) Interpret these: O, O_2, 2O, O_3.

2. What is the formula of ammonia gas? State fully how this formula is found by experiment.

3. (a) Complete and balance $Pb(NO_3)_2 + - = PbCl_2 + -$. (b) Write the name and formula of the sodium salt of permanganic acid, of the sulphide of bismuth, of the hydroxide of aluminium. (c) What is the name of HCO_3-, of $H+$, of $OH-$?

GROUP V. (*Answer two questions in this group.*)

1. (a) What is the per cent of water in potatoes? (b) How would you test coal ashes for iron?

2. Write 50 words on (a) enzymes or on (b) fuel value of food.

3. What is copperas, blister copper, corrosive sublimate, chalk, ferrochrome, lime, alum, limewater, sterling silver, a diamond carat? What is meant by (a) a water analysis and (b) decomposition of water by electricity?

SOLUTIONS AND ANSWERS.

254. *A Correction.*

The answers by Mr. Hughes should read 36° 26′ 31.7″ and $E = 206 \div 2 + 500 \cos A = 206 \div 804 = .256$.

269. *Proposed by W. A. Hedrick, Central High School, Washington, D. C.*

What do you think of the questions so often asked by the psychologists to which one and only one answer is possible, as in Starch's *Educational Measurements?* They are like this taken from Hall & Bergen, p. 189.

"Supply the omitted word."

Two points so placed with respect to a lens that an object placed at either of them will have an image at the other are called .... of the lens.

This question suggests another. How many readers of this department would like to get together on a set of tests in physics, or chemistry, or other science corresponding to Courtis's *Practice Tests in Arithmetic?* (Write to the Editor of this department at University School.)

The following have signified their desire to go ahead with tests along the line proposed either in physics or chemistry:

S. R. Powers, University of Minnesota High School.
T. R. Wilkins, University High School, Chicago.
P. C. Hyde, Newark Academy, Newark, N. J.
Arthur B. Bucknam, Crosby High School, Waterbury, Conn.
Walter N. Lacy, Anglo-Chinese College, Foochow, China.
Franklin T. Jones, University School, Cleveland, Ohio.

Others who desire to get into touch with this movement will please communicate at once with the Editor of this department.

RESEARCH IN PHYSICS.

Conducted by Homer L. Dodge.

State University of Iowa, Representing the American Physical Society.

It is the object of this department to present to teachers of physics the results of recent research. In so far as is possible, the articles and items will be nontechnical, and it is hoped that they will furnish material which will be of value in the classroom. Suggestions and contributions should be sent to H. L. Dodge, Department of Physics, State University of Iowa, Iowa City, Iowa.

THE DETERMINATION OF THE ELECTRONIC CHARGE *e*.

The importance of the value of the charge of the electron made its exact measurement a much desired accomplishment. It remained for an American physicist, Professor Robert A. Millikan of the University of Chicago to carry out this work. In the introduction to *The Electron*[1] he says: "Science, like a planet, grows in the main by a process of infinitesimal accretion. Each research is usually a modification of a previous one; each new theory is built like a cathedral through the addition of many builders of many different elements." This work of Professor Millikan's grows out of, and is based upon, the results of earlier investigations carried on in the Cavendish laboratory.

The first attempt at a direct determination of e was made by Professor J. S. Townsend in 1897, who used a method depending upon the condensation of saturated water vapor on ions. The final value depended upon a measurement of the total electronic charge, the total weight of the cloud, and the average weight of the droplets. This last was found by observing the rate of fall of the cloud under gravity and computing the mean radius by the aid of a purely theoretical formula known as Stokes's Law. He divided the weight of the cloud by the average weight of the droplets to obtain the number of droplets. This he assumed to be the same as the number of ions. Dividing the total charge by the number of ions he found the average charge carried by each ion, that is, e.

A second attempt was made by Sir J. J. Thomson by a method resembling that of Townsend in all its essential particulars. Later, H. A. Wilson devised a further modification. All three methods, however, were weak in the following particulars: (1) the assumption that the number of ions is the same as the number of drops; (2) the assumption of Stokes's Law, which might well be expected to be in error when applied to small drops; (3) the assumption that the droplets were all alike and fell at the same rate, uninfluenced by evaporation or other causes of change; (4) the assumption of no convection currents in the gas when the rate of fall of the cloud was being measured. There were, in addition, experimental difficulties peculiar to each method. Consequently the values of e resulting from this early work were quite uncertain, having a probable error of several per cent.

In 1906 Professor Millikan repeated Wilson's experiment, securing more consistent results; but, what is more important, he rapidly improved the methods of measuring e until in 1909 he was able to make all the measurements on individual droplets. Thus he was able not only to eliminate ultimately all the questionable assumptions and experimental uncertainties involved in the cloud method but also to examine the

[1] This article is based upon, and quotes freely from, a portion of *The Electron*, by Professor R. A. Millikan, a book just published by the University of Chicago Press (see page 762 of the November issue of this journal). It deals with the measurement of e, not only describing the author's remarkable work but also giving the historical background and the significance of the value of the electronic charge in connection with various branches of physics. It is written in the easy, readable style characteristic of Professor Millikan and brings this particular line of research before students of physics who do not have ready access to original sources. Although not a "popular" book, it is adapted to the general reader.

properties of individual isolated electrons and to determine whether different ions actually carry one and the same charge. The final result of the work has been both an exceedingly accurate determination of *e* and conclusive proof of the atomic nature of electricity, a thing predicted by many but heretofore impossible of experimental test.

In the earlier work he was concerned with a plan for eliminating the error due to the evaporation of the droplets of water and sought to obtain an electric field strong enough to exactly balance the force of gravity upon the cloud. It was found not possible to balance the cloud but it was possible to do something much better, namely to hold individually charged drops suspended for a number of seconds. Later, while working with these "balanced drops," he noticed that now and then one of them would suddenly change its charge and begin to move up or down in the field, evidently because it had captured an ion, in the one case a positive, and in the other a negative. This made it possible to measure the charge carried by a single atmospheric ion. For by taking two speed measurements on the same drop, one before and one after it had caught an ion, he could eliminate entirely the properties of the drop and of the medium and deal with a quantity which was proportional merely to the charge on the captured ion itself.

In the fall of 1909 an apparatus was constructed with which it was possible to use oil drops which, being free from evaporation, could be held under observation for long periods. Two horizontal brass plates, 25 cm. in diameter and 16 mm. apart, formed the chamber in which the drops were studied. Drops of oil were blown with an atomizer into a chamber above the upper plate. These minute droplets, most of them having a radius of the order of one-thousandth of a millimeter, slowly fell in the chamber and occasionally one would find its way through a minute pin hole in the center of the upper plate. These oil drops were illuminated by a powerful beam of light projected into the space between the plates and when viewed through a short focus telescope appeared as bright stars against a black background.

The drops were found in general to have been slightly charged by the frictional process involved in blowing the spray, so that if the field were thrown on in the proper direction they would be pulled upward. Just before the drops reached the upper plate the plates would be short-circuited, when the droplets would fall under gravity until close to the lower plate. Then the direction of the motion would be again reversed by throwing on the field. In this way the drop could be kept moving back and forth between the plates for a long time.

But the interesting thing that happened was this: whereas the velocity of any drop under the influence of gravity was the same in all cases, under the influence of the electric field the velocity changed from time to time. The change was, however, always by the same amount or by a small integral multiple of this amount. Thus when the drop was positive a decrease in speed by one of these amounts indicated the capture by the droplet of a negative ion, while an equal increase in speed meant that a positive ion had been caught. Although the nature of thousands of ions was observed in this way, in no case was there found to be a change which did not correspond to the value of the smallest charge ever captured or else a very small multiple of that charge.[2]

In this connection it should be mentioned that these same experiments furnished the proof that all static charges both on conductors and insulators are built up of electrons, for it was found that the initial velocity

[2]See page 554 of the June number of this journal.

of a droplet under the influence of the field was in all cases a multiple of the difference of velocity associated with the electronic charge. Experiments were tried on thousands of drops in different media, some of the drops being made of nonconductors like oil, some of semiconductors like glycerin, some of excellent metallic conductors like mercury. In every case, the initial charge placed upon the drop by the frictional process, and all the dozen or more charges which resulted from the capture by the drop of ions, were found to be exact multiples of the smallest charge caught from the air.

We have seen how the atomic nature of electricity was proved and that it is possible to measure the effect of a single unit of charge. We will now examine into the method of getting at the value of the charge. Millikan showed that the velocity with which a drop moves is proportional to the force acting on it and independent of the electric charge except as it affects the force. Accordingly,

$$\frac{v_1}{v_2} = \frac{mg}{\mathrm{F}e_n - mg}$$

in which v_1 and v_2 are the velocities of the drop under the influence of gravity and of the electric field respectively, F the field intensity, e_n the charge on the drop, m the mass of the drop and g the gravity constant. If the mass of the drop were known, it would be an easy matter to evaluate e, but the mass of a single small drop can be known only through Stokes's Law already referred to, which gives the velocity v_1 of a drop of radius a and density σ falling under the influence of gravity in a medium of viscosity η as follows:

$$v_1 = \frac{2ga^2\sigma}{9\eta}$$

Combining this with the first equation and eliminating m by means of the formula

$$m = 4/3\pi a^3\sigma$$

we have

$$e_n = \frac{4}{3\pi}\left(\frac{9\eta}{2}\right)^{3/2}\left(\frac{1}{g\sigma}\right)^{\frac{1}{2}}\frac{(v_1+v_2)v_1^{\frac{1}{2}}}{\mathrm{F}}$$

which contains only constants or easily measured quantities.

On finding that drops of different sizes gave different values of e, Millikan questioned the validity of Stokes's Law and initiated a series of elaborate experiments at the Ryerson laboratory to find the correction which must be applied in the case of very small drops. At the same time the coefficient of viscosity of air, which appears in the formula in the 3/2 power, was determined with great accuracy and a new apparatus of great refinement was constructed. After about two years of work the final value of e was announced in 1916 as follows:

$$e = 4.774 \pm .005 \times 10^{-10} \text{ absolute electrostatic units.}$$

To indicate the importance of this result, we quote from *The Electron:* "As soon as e is known it becomes possible to find with the same precision which has been attained in its determination the exact number of molecules in a given weight of any substance, the absolute weight of any atom or molecule, the average kinetic energy of agitation of an atom or molecule at any temperature, and a considerable number of other important

molecular and radioactive constants. In addition, it has recently been found that practically all of the important radiation constants like the wave-lengths of X-rays, Planck's h, the Stefan-Boltzmann constant σ, the Wien constant c_2, etc., depend for their most reliable evaluation upon the value of e. In a word, e is increasingly coming to be regarded, not only as the most fundamental of physical or chemical constants, but also the one of most supreme importance for the solution of the numerical problems of modern physics."

ARTICLES IN CURRENT PERIODICALS.

American Botanist, for August; *Joliet, Ill.; $1.25 per year, 35 cents a copy:* "Plant Life on the Peaks," Blanche H. Soth; "How Brazil Nuts Grow," H. E. Zimmerman; "Uses of Cacti," Paul G. Russell.

American Journal of Botany, for November; *Brooklyn Botanic Garden; $5.00 per year, 60 cents a copy:* "Effect of Soil Temperature on the Growth of Bean Plants and upon Their Susceptibility to a Root Parasite," Donald Reddick; "The Development of Cortinarius Pholideus," W. H. Sawyer, Jr.; "Leaf-structure as Related to Environment," Herbert C. Hanson.

American Mathematical Monthly, for November; *5548 Kenwood Ave., Chicago; $3.00 per year:* "The Significance of Mathematics," E. R. Hedrick; "The Linear Function and the Line," Joseph Nyberg; "The Graph of $F(x)$ for Complex Numbers," A. F. Frumveller; "An Intrinsic Equation Solution of a Problem of Euler," P. R. Rider.

Geographical Review, for November; *Broadway at 156th Street, New York City; $5.00 per year, 50 cents a copy:* "Aeronautical Maps and Aerial Transportation," Henry Woodhouse; "Saving the Crops from Injury by Frost," Alexander McAdie; "The Virgin Islands of the United States," Theodore de Booy; "The Lau Islands of Fiji," W. G. Foye; "The Distribution of British Cities, and the Empire," Mark Jefferson.

Journal of Educational Psychology, for October; *Baltimore, Md.; $2.50 per year, 30 cents a copy:* "The Power of the Eye to Sustain Clear Seeing under Different Conditions of Lighting," C. E. Ferree and Gertrude Rand; "The Effect of External Incentives on Improvement," J. C. Chapman and R. B. Feder; "A Detailed Study of Whipple's Range of Information Test," J. C. Bell; "Aphasic Performance in the Terman Vocabulary Test," F. L. Wells.

Journal of Geography, for December; *Madison, Wis.; $1.00 per year, 15 cents a copy:* "Suggestions for Teaching Elementary Geography," R. H. Whitbeck; "The Food Surplus of South America Available in Time of War," George B. Roorbach; "The Use of Geographic Materials," Robert M. Brown; "Wheeling, West Virginia (Map)," Helen M. Garden; "The Condition of Geography in the High School and Its Opportunity," Carl O. Sauer; "Newfoundland," E. M. Jones.

Photo-Era, for October; *Boston, Mass.; $2.00 per year, 20 cents a copy:* "System in the Studio," Pirie MacDonald; "Tone-Rendering and Quality in Gaslight-Papers," T. D. Tennant; "A Use for Old Bromide Paper," S. Watmough Webster; "Picturing Children Afield," Charles J. Adams; "Focusing in Portraiture"; "Six Years, Twelve Tears and a Pinhole-Camera," Edwin B. Whiting; "Holding a Vest-Pocket Camera," Charles R. Denton; "Restoring Daguerreotypes," C. E. Bold.

Physical Review, for November; *Ithaca, N. Y.; $6.00 per year, 60 cents a copy:* "Oscillating Systems Damped by Resistance Proportional to the Square of the Velocity," J. Parker Van Zandt; "An Experimental Investigation of the Total Emission of X-Rays from Certain Metals," C. S. Brainin; "The Pressure Increase in the Corona," Earle H. Warner; "The Ionizing Potentials of Gases," A. L. Hughes and A. A. Dixon; "A Determination of the Ratio of the Specific Heats of Hydrogen at 18°C. and —190°C.," Margaret Calderwood Shields; "Theoretical Considerations Concerning Ionization and 'Single-Lined Spectra,' " H. J. Van Der Bijl; "The Parallel Jet High Vacuum Pump," William W.

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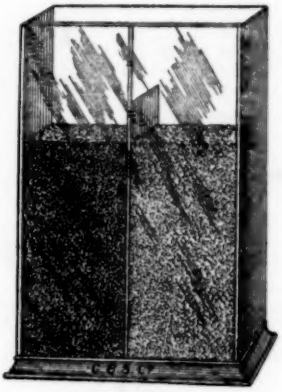

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School Review, for November; *University of Chicago Press; $1.50 per year, 20 cents a copy:* "A Statistical Study of the Scholastic Records of 404 Junior and Non-Junior High-School Students," Paul Clifford Stetson; "Supervised Study and the Science Laboratory," Elliot R. Downing; "The Junior High School," L. McCartney; "The Supervision of Extra-Curricular Activities," Elmer Harrison Wilds.

School World, for November; *Macmillan Company, London, Eng.; 7s. 6d. per year:* "The Secondary-School Examinations Council"; "Books on the Method, Philosophy, and History of Science," R. A. Gregory; "Modern Humanistic Studies," C. H. C. Osborne; "Schools and Public Libraries," John Swain; "Standardising and Competitive Examinations."

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Junior High School Mathematics, by William L. Vosburgh, Boston Normal School. Pages vii+146. 13×19 cm. Cloth. 1917. $0.75. The Macmillan Company, New York City.

Laboratory Manual in General Chemistry, by William J. Hale, University of Michigan. 13.5×19 cm. Cloth. 1917. $1.50. The Macmillan Company, New York City.

A Textbook in the Principles of Science Teaching, by George R. Twiss, State High School Inspector, Columbus, Ohio. Pages xxiv+486. 14.5×20.5 cm. Cloth. 1917. $1.40. The Macmillan Company, New York City.

Stony Island. A Plea for Its Conservation, by Zonia Baber, School of Education, University of Chicago. 16 pages. 15×23 cm. Paper. 1917. The University of Chicago Press.

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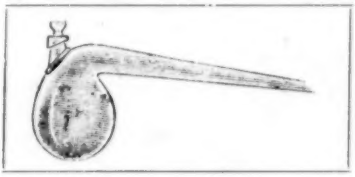

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